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MARSIS Radar: GEOGRAPHICAL VISUALIZATION TOOL REQUIREMENTS

Issue 2, Rev 0

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1 Introduction

The Geographical Visualization Tool (GVT) was designed in order to access different kind of information related to the mission and display them in different formats, with intensive graphical outputs.

The aim of the application is that to be a data merging (fusion utility) to optimize the planning process and the scientific exploitation phase of MARSIS data. The design modularity should allow the addition of future functionalities particularly envisioning additional requirements from the science community and the requirements of forthcoming missions (like MRO/Sharad).

The GVT can do also simple elaboration of the data before their graphical visualization.

In conclusion, the GVT is a flexible and modular software that allows the utilization of other mission data.

2 GVT general overview

GVT characteristics:

- Visualize any data contained in the PCADB
 - Parameters estimated from MOLA data
 - Ground tracks
 - Timelines
 - Targets
 - Magnetic fields
- Visualize Level 2 data
 - The Official Level 2 produced by the Level 2 Tool in PDS format;
 - The Level 2 produced by the Quick Look Tool (not PDS format);
 - The Level 2 produced by the Marsis Simulator (not PDS format);

In particular the GVT is able to plot in the same figure, if requested, all the Level 2 available for a selected frame (antenna, frequency and Doppler filter).

- Visualize Level 3 data: in particular the GVT is able to plot in the same figure, if requested, all the possible combination of Level 2 and Level 3 data (see for more details the section 4.8) available for a selected frame (antenna, frequency and Doppler filter).
- Import and visualize external images (.gif and /or .jpeg)
- Correlate and interpolate different dataset and
 - Visualize merged dataset
 - Visualize differential datasetin the form of maps and profiles
- Allow to the operator, through a graphical interface, to zoom into a image and visualize the orbital profiles associated to a particular area of the map.



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- Save (with file .gif and/or .jpeg) and print all the maps, diagrams and lists of parameters produced starting from the PCADB, the Level 2 and the MOLA data.
- Export selected Level1bB (quick look version), Level 2 (real and quick look version) and MOLA data set.

In fig. 1 is represented the data flux involving the GVT Tool.

We wish to underline that the graphical interface of the GVT allows the operator, with an intensive use of “windows” (as commercial product: Windows, Matlab etc.), to manage easily all the feature of the tool that are described with more details in the following sections.

Furthermore the GVT can operate with multi session mode.

In conclusion the user is able to visualize all the data set enlisted above (and described with more details in the following sections), selecting the area (with the coordinates in longitude and latitude of two points or with the choice of a particular target stored in the PACDB) or the orbit number (or set of orbits).

3 GVT Input

The main sources of input for the GVT will be the PACDB and a Local Archive.
In particular the most important data will be the following:

From PCADB:

- Parameters (enlisted in a specific section) estimated from MOLA data;
- Targets and point of interest;
- Mars Magnetic Field Distribution;
- MEX Ground Tracks;
- Marsis Orbits Timeline;

From Local Archive:

- Marsis Level 1B Data (Quick Look version, no PDS);
- Marsis Level 2 Data (official, Quick Look version and Simulator version);
- Quick Look Data;
- Marsis Level 3 Data;
- Marsis Simulator Data;
- MOLA data;
- External thematic maps;

Moreover the GVT is able to import geographically referenced images of Mars in image format and to superimpose different datasets (parameters from MOLA, ground tracks, timelines, targets, heights contour ...).



GVT: DATA FLUX

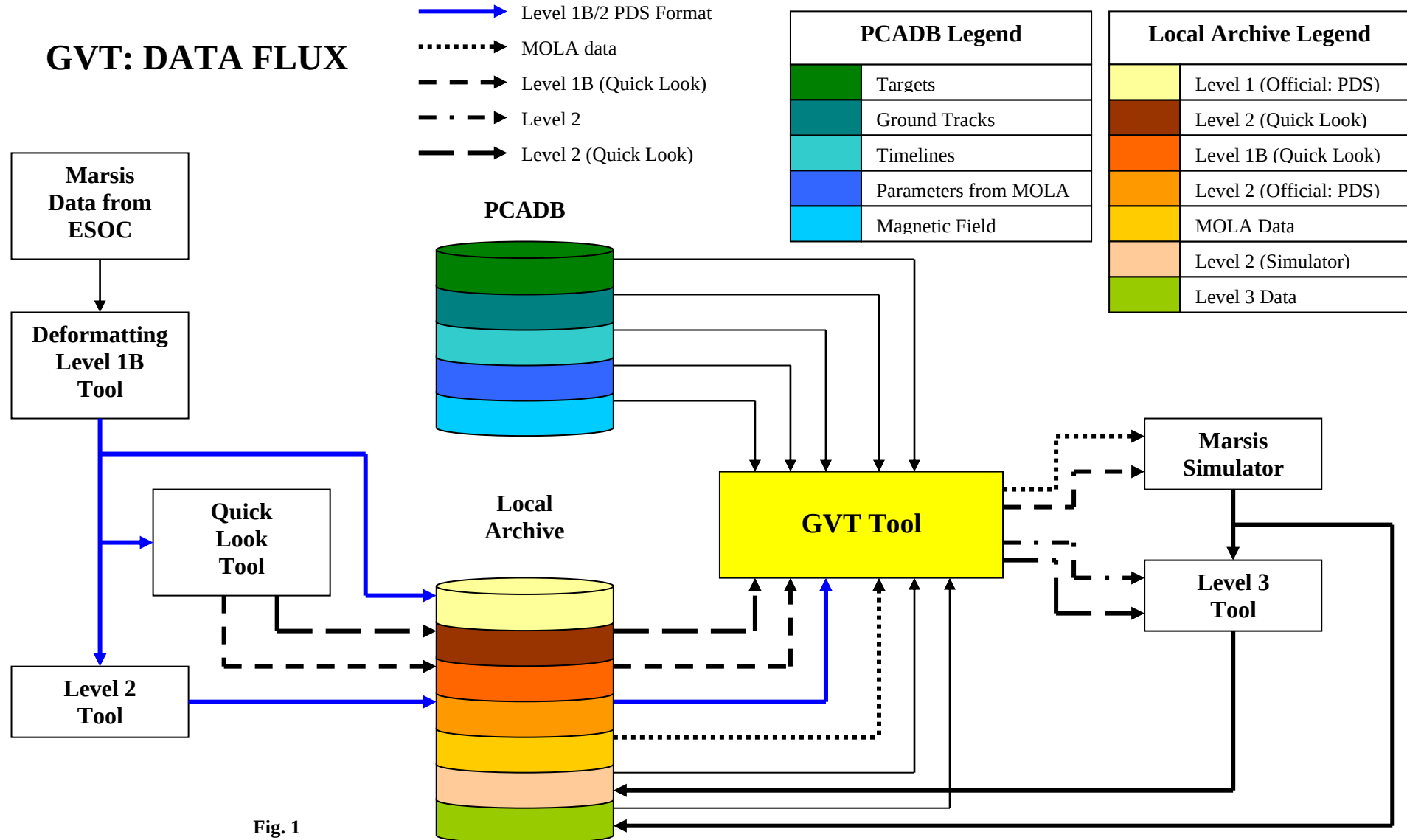


Fig. 1



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4 GVT Output

The principal task of the GVT is the creation of maps and diagrams of selected data. Of course not all the data enlisted above will be available at the same time, this means that the GVT will become a more powerful instrument of analysis with the progress of the Marsis mission.

The following subsections will describe with more details the GVT functionality related to specific sets of inputs.

Concerning all the data geographically referenced (see in particular the sections 4.1, 4.2 and 4.4), the GVT is able to produce maps with two type of projection. The first type is the Mercator projection (see figures 4, 5 and 6 in App. 2), for the entire planet and/or selected areas. While the second one is the polar projection, only for the polar caps ($-90 \div -60$ and $60 \div 90$ degrees of latitude).

4.1 MOLA Data

We wish to recall that MOLA (Mars Orbital Laser Altimeter) from the Mars Global Surveyor (MGS) mission, is a laser altimeter whose data can be reduced to topographic height and, due to the time interval between the measurement, are spaced of about 300 m.

Considering the huge dimension of the MOLA data and the typical resolution of Marsis, that will be 5 Km x 10 Km in the along track and cross track directions respectively, the GVT shall be able to build the maps of Mars starting from the mean value of the surface height z_i described in the following section.

These maps of Mars will be used as basic reference for all the GVT applications. In particular the GVT is be useful to support the Planning and Commanding activity superimposing the MEX Ground Tracks with the targets and point of interest on the maps of Mars to check the correspondent Orbit Timeline elaborated by the Planning Tool.

Anyway, the GVT can use the original MOLA data to reproduce maps and diagrams with more accuracy if necessary. For more details see Appendix 3.

4.2 Parameters estimated from MOLA Data

Taking into account the availability of MOLA data in a Local Archive and following recent attempts to describe the structure of the planets surface by means of fractals, we will try to introduce this model in our instrument performance evaluation. In particular it was outlined that Mars surface point to point slope seems to display a power law behavior vs. the lag distance typical in fractal profile and the parameter that drives the scaling behavior is called Hurst exponent H . Therefore our approach was referred to the estimation of the fractal parameters, in order to estimate preliminarily the surface backscattering models.

According to the MARSIS spatial resolutions, we have selected regions of the 10×10 km², overlapped of 5 Km in the perpendicular directions, and thence, after subtraction of the best



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fitted facet, by the logarithm of the Allan variance, H was estimated. The same profiles and the same sections was also processed to validate the H coefficient and estimate the correlation length.

Therefore in conclusion for each region of $5 \times 5 \text{ km}^2$ a set of parameters, called local parameters, was estimated and stored in the PACDB (the complete list is in Appendix 1).

Another set of parameters, called global parameters, was also evaluated for all points in the circular area (radius 10, 50 and 100 km), with reference to each point under investigation. Also these parameters (see Appendix 1) are stored in the PACDB.

Of course, the GVT is able to represent with maps all the evaluated parameters (few examples are in App. 2) and to superimpose the contour of the heights for a quick evaluation of the behaviours, with the possibility to easily select some areas to magnify. In particular the user can visualize the values of the parameter selected regrouping them in five range fields (see fig. 11 in Appendix 2)

4.3 MEX ground tracks, targets and point of interest

A not secondary task of the GVT tool will be a visual recognition of the orbit ground tracks with the indication of the targets and point of interest proposed by the scientific community. Examining these maps, the Marsis team could prepare a priority list before the Planning Phase avoiding wastes and conflicts, when it is possible. In the following figure there is a simple example useful to understand what we mean.

The GVT can superimpose the ground tracks and the targets all over the maps described in the previous section.

The targets is represented by small icons; with a click on these icons the operator will open a window with a brief description of the target characteristics.

Concerning the orbits, the ground tracks will be described by their numbers with the indication of the pericenter, while the Sun Elevation will be described using different colorbars, located at the side of the screen, according to the related orbits. In the scale of the colors the white corresponds to the highest positive Sun Elevation (day side), while the black corresponds to the lowest negative Sun Elevation (night side).

4.4 Mars Magnetic Field Distribution

As it is well known Mars have no appreciable global intrinsic magnetic fields, but the MGS has established that the planet has strong (up to 1600 nT) local magnetic fields, probably related to properties in the martian crust.

The magnetic field lines of this crustal fields are closed in the lower ionosphere and the associated magnetic perturbations are detected also in the upper ionosphere.



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Flux densities with strength exceeding 200 nT were measured at heights of 400 Km above the surface, but in some regions this influence arrive up to 700 Km.

In the above described scenario, the long wavelength and linearly polarized radar, MARSIS, could fly above a zone where the effects of both the magnetic field and the electron density in the ionosphere, in the worst case could combine. In this case the signal could be attenuated very heavily.

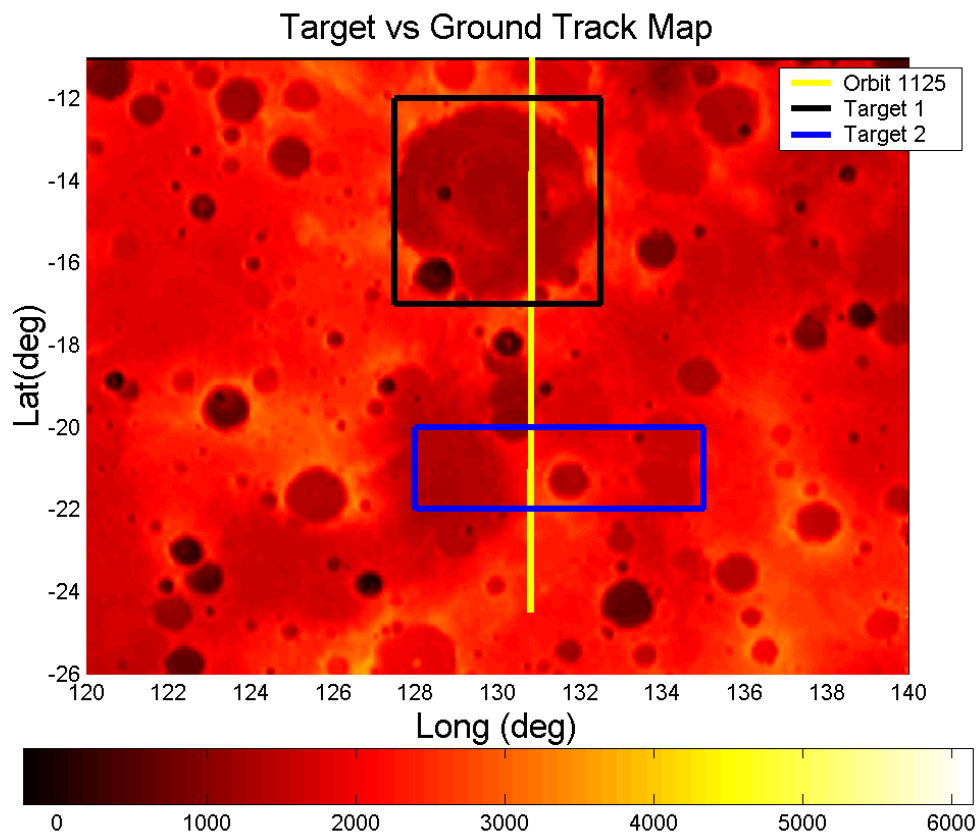


Fig. 2: Ground track of the orbit 1125 with two hypothetical targets

For this reason the GVT is be able to map the magnetic field distribution, based on the MGS observation and stored in the PCADB. Moreover since the magnetic fields effects are strictly dependent by the behaviour of the ionosphere, the GVT is be able to superimpose also the ground tracks of selected orbits.

The user can choose the orbits of interest not only with the indication of the number, but also with the indication of the sun elevation.

This means that the GVT can visualize all the orbits passing through a selected region, of variable dimensions, otherwise a part of these selecting a certain interval of orbit number or a particular range of sun elevation.



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Furthermore, there is the possibility to superimpose the contour of the heights and all the known targets on the previous map, in order to estimate the impact of the magnetic fields on the planning operations.

In conclusion the GVT is able to perform all the features described for the other parameters in the previous sections, also for the data related to the magnetic field.

In the fig. 3 there is a simple example of the Radial Magnetic Fields with the ground track of the orbit 1125.

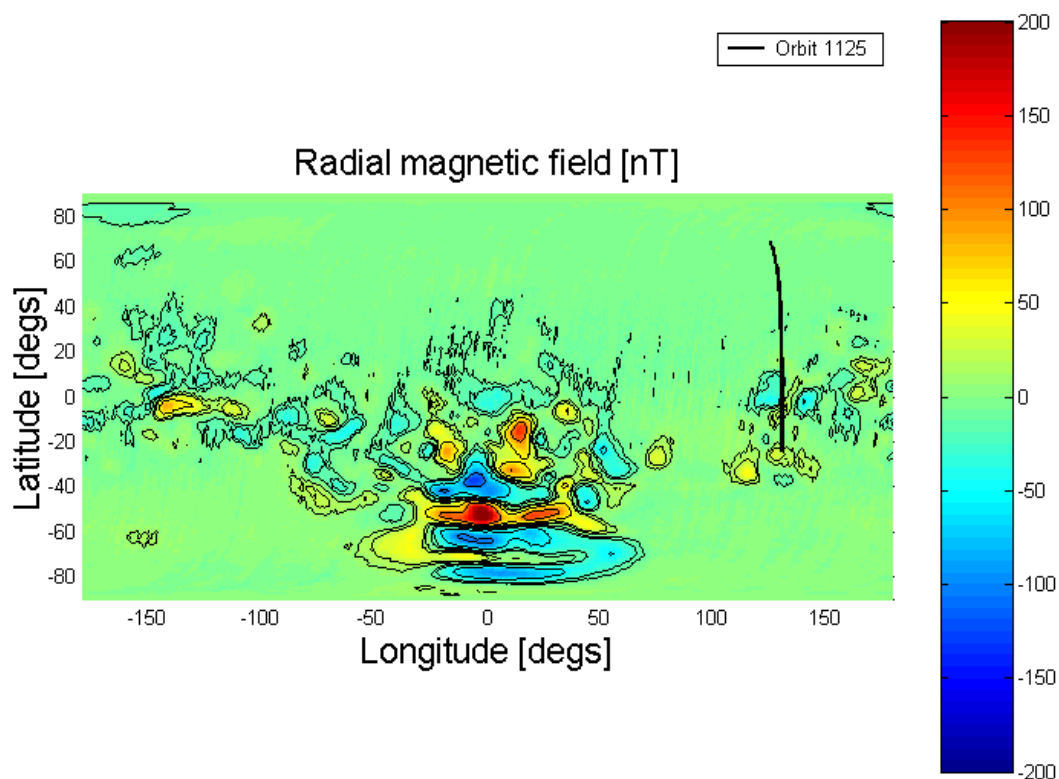


Fig.3 Radial Magnetic Fields with the ground track of the orbit 1125.

4.5 Marsis Orbits Timeline

The Orbit Timeline shall be produced by the Planning Tool and shall be stored in the PCADB.



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The GVT is able to plot the timeline at the side of the maps that shows the correspondents ground tracks with a bar of different colors according to the operative modes (this is the same method used by the Planning Tool to show the timelines elaborated), with the indication of the frequencies and the timing. Furthermore the GVT can show with spots on the ground tracks the timing (the start and the end of each operative mode) of the timelines under examination.

Since the parameters shown in the section 3.2 are the same used by the Planning Tool, it is obvious think to use the GVT to check the Orbit Timeline.

Starting from the maps produced with the parameters available in the PCADB and also with the heights coming from the MOLA data (and described in the previous sections), is requested, in particular, to the GVT to visualize around the ground track of a specific orbit a strip, of dimensions depending from the radar swath or settable by the user (see App. 3) accordingly with the Timeline characteristic (frequency, altitude, range resolution, ...).

The GVT can show the results with maps (2D and 3D) and profiles.

This feature is very useful not only to support the Planning phase but also to understand the real data produced by Marsis. In fact, an important problem is related to the clutter in the cross track direction. In particular conditions could happen that the reflected echo of a scatterer in the cross-track direction, could hide the weak echo of the subsurface or, in alternative, the clutter could be interpreted as a subsurface echo. Since the task of Marsis is to “see” under the surface, this situation is very dangerous.

4.6 Marsis Data Product

The user can select a particular zone of Mars to analyze, writing the coordinates of interest, all the information and the data related to the Marsis mission. The GVT will list all the orbits that cover the area visualizing the ground tracks on a Mars map based on the MOLA data, specifying the status of each orbit. For example if the orbit has been executed or no, if is available his Level 2 or no, and at the end if are available information of Level 3.

It is worth noting that the information of Level 3 will not in PDS format as the Level 2, but in a more simple format (file.DAT) and then the GVT shall be able to handle this format. Now the user shall be able to analyze each orbit or set of orbits in detail, using the Basic Functionality that following:

Basic Functionality

After that the complete list of orbits related to a selected zone has been given by the GVT, the user shall be able to do a more accurate choice in three different way:

- For orbit: the user will select the related number;
- For Operative Mode: the user will select the Operative Mode of interest and the GVT will give all the orbits that contain the Operative Mode chosen;



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- For frequency: the user will select the frequency of interest and the GVT will give all the orbits that contain the frequency chosen.

Accordingly with the selection operated above, the user to access to the necessary information shall set in the right way the following fields:

1. Time: the user will be able to analyze all the orbit or only a part of this. In the second case the user will indicate the time interval of interest.
2. Operative Mode: the user will be able to analyze all the operative modes that are present in the time interval choose at the point 1). Otherwise, he will select only a particular operative mode.
3. Frequency: the user will be able to select the frequency (or frequencies) of interest, accordingly with the point 2).
4. Antenna: the user will be able to select both antennas (Dipole and Monopole) or only one, accordingly with the point 2).
5. Doppler Filter: the user will be able to select the numbers of the filters of interest accordingly with the points 2) and 4).

With the user inputs listed above, the GVT can visualize module, phase and the square modulus (the power) of the selected signals. The user will be able to print and/or save the images (if requested) in a local memory.

The GVT can visualize not only single frames in 2D format (x=time, y=power/phase), but also the complete series of all the frames (for a specific Doppler filter) collected during an Operative Mode with a radargram (x=frames, y = time, z = power (colorbar)in 2D or 3D format).

Since the signals in the Level 2 are represented in module and phase, to obtain the power, the GVT will use the following algorithm:

$$20 \log_{10} M$$

where M is the module of the signal.

It is worth noting that even if there is the same operative mode for a large part of an orbit, it could have different frequencies, than the realization of a radargram is possible only for fixed frequencies. For instance if during the operative mode SS4 the frequency change three times, the GVT can produce three radargrams.

It is important to underline that, starting from a radargram, the user can select a set of frames that the GVT will visualize separately with 2D plot. Furthermore from the frames number the GVT is able to obtain, with a good approximation, the related coordinates (Latitude and Longitude) of the area of Mars under examination. The next step is the representation of the surface map using the MOLA data, or the other parameters stored in the PCADB and described in 4.2, and the algorithm showed in Appendix 3(see A3.2) as anticipated in section 4.5.

The last step is the exportation by the GVT of the surface selected during the previous steps.



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Moreover the GVT can convert and to export in a matrix (x = time, y = power) of a selected format (file. dat) the signals, for advanced elaboration (Level 3).

4.7 Marsis Simulator and Quick Look Data Product

The GVT is able to visualize also the data produced by the Marsis Simulator (Level 2 not Official) that, as those elaborated by the Level 3, will not in PDS format. This feature of the GVT is be very important to support the Level 3 data inversion phase. In fact the Marsis simulator shall be used to check all the models (ionosphere, backscattering, ...) that are the foundations for the data processing and data inversion. For this task the GVT it is irreplaceable, showing the results of the real and simulated data

Furthermore the GVT can visualize and export the not Official Level 2 (not PDS format, 32 bit floating point) produced by the Quick Look Tool, and to export the Level 1B also reorganized by the Quick Look Tool (this is a 32 bit floating point version, not PDS format). The structure of these data set (both stored in the Local Archive) is described in Appendix4.



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4.8 Level 3 Data Product

The GVT is able to visualize the data produced by the Level 3 phase(data inversion). These data are of two different types, representatives of successive results and elaborations:

- The signal after the Level 3 elaboration. This data set is represented by:
 - The ideal surface backscattering obtained starting from the MOLA data (original or interpolated);
 - The subsurface echo extracted from the Level 2 data sets;
 - The subsurface echo extracted from the Level 2 data sets and mediate with different frequencies (if possible) to obtain a signal independent from the frequency;

The GVT can visualize in the same figure, if request, all the Level 3 data described above, and also the connected data of Level 2, for a selected frame.

- The parameters extracted (for instance the dielectric constant and the roughness of the surface, the depth and the dielectric constant of the successive subsurface layers).

This feature shall be perform in two different ways:

- Reproducing file image (.jpeg, .giff) produced by other commercial tools (only for the second type of parameters);
- Visualizing specific data sets, stored in a Local Archive, and organized as described in Appendix 4.

All the software format and organization about the Level 3 data is described in detail in Appendix 4.

5 Conclusion

In conclusion the GVT shall basically provide a MOLA-derived representation of Mars surface and the capabilities to superimpose on that different sets of data including Geological maps, Targets and points of interest and Marsis data product.

The user shall be able to use the application to create views of a portion of the surface of Mars based on an area of interest or a portion of Ground Track. The view shall be able to be projected in different ways. Altimetry view shall also be made available as well as MARSIS operating modes and basic commanding parameters. The capability to produce global thematic maps shall also be provided.

The design of the application shall be highly modular in order to permit the expansion to other applications. The development environment should guarantee easy porting to different platforms.



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Appendix 1

Parameter	Description	PACDB name	Type
Local Parameters			
α_x	surface slopes of flat estimated region (along x direction)	Alpha_X	Real
α_y	surface slopes of flat estimated region (along y direction)	Alpha_Y	Real
z_i	mean value of the surface height	Alt_Z	Integer
σ_i	rms surface	Sigma_Z	Real
L_{xi}	correlation length (along x direction)	CLx	Integer
L_{yi}	correlation length (along y direction)	CLy	Integer
H_{xi}	Hurst coefficient (along x direction)	Hx	Real
H_{yi}	Hurst coefficient (along y direction)	Hy	Real
m	slope	Slope_m	Real
$L_i = \frac{2}{\left(\frac{1}{L_{xi}} + \frac{1}{L_{yi}}\right)}$	Correlation length of a single region of 5.5 Km	CL_med	Integer
$H_i = \frac{(H_{xi} + H_{yi})}{2}$	Hurst coefficient of a single region of 5.5 Km	H_Med	Real
Global Parameters (R=10 Km, R=50 Km, R=100 Km)			
$\bar{\sigma}_i = \left[\frac{1}{n} \cdot \sum_{j=1}^n \sigma_j \right]$	Mean value	Sigma_med	Real
$\sigma_{j \max}$	Maximum displacement	Sigma_max	Real
$\sigma_{j\sigma}$	Standard deviation	Sigma_dev	Real



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$\bar{\alpha}_{xi} = \left[\frac{1}{n} \cdot \sum_{j=1}^n \alpha_{xj} \right]$	Mean value (along x direction)	AlfaX_med	Real
$\alpha_{xj\max}$	Maximum displacement (along x direction)	AlfaX_max	Real
$\sigma_{xj\alpha}$	Standard deviation (along x direction)	AlfaX_dev	Real
$\bar{\alpha}_{yi} = \left[\frac{1}{n} \cdot \sum_{j=1}^n \alpha_{yj} \right]$	Mean value (along y direction)	AlfaY_med	Real
$\alpha_{yj\max}$	Maximum displacement (along y direction)	AlfaY_max	Real
$\sigma_{yj\alpha}$	Standard deviation (along y direction)	AlfaY_dev	Real
$\bar{L}_i = \frac{2}{\frac{1}{n} \sum_{j=1}^n \left(\frac{1}{L_{xj}} + \frac{1}{L_{yj}} \right)}$	Mean value	CLg_med	Integer
$L_{i\max}$	Maximum displacement	CLg_max	Integer
σ_{iL}	Standard deviation	CLg_dev	Integer
$\bar{H}_i = \frac{1}{n} \cdot \sum_{j=1}^n H_j$	Mean value	Hg_med	Real
$\bar{H}_{i\max}$	Maximum displacement	Hg_max	Real
σ_{iH_i}	Standard deviation	Hg_dev	Real
$\sigma_{hi} = \sqrt{\bar{\sigma}_i^2 + (\sigma_{xi\alpha}^2 + \sigma_{yi\alpha}^2) \cdot 25 \cdot 10^6} \text{ (m)}$		Sigma_H	Real
$\bar{m}_i = \sqrt{2} \frac{\bar{\sigma}_i}{\bar{L}_i}$		Slope_g	Real



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$\bar{s}_i(\lambda) = \sqrt{2} \cdot \frac{\bar{\sigma}_i \lambda^{H_i-1}}{L_i^{H_i}}$ for $\lambda = 166m$ Band I		Lambda	Real
$\Delta\sigma_i _{\max} = (\sigma_{i\max} - \bar{\sigma}_i) = k_\sigma \cdot \bar{\sigma}_{i\sigma} \rightarrow k_\sigma$		Ksigma	Real
$\Delta\alpha_{xi} _{\max} = (\alpha_{xi\max} - \bar{\alpha}_{xi}) = k_{\alpha x} \cdot \sigma_{xi\alpha} \rightarrow k_{\alpha x}$		KalfaX	Real
$\Delta\alpha_{yi} _{\max} = (\alpha_{yi\max} - \bar{\alpha}_{yi}) = k_{\alpha y} \cdot \sigma_{yi\alpha} \rightarrow k_{\alpha y}$		KalfaY	Real

Tab. 1



Appendix 2

The following figures are just few examples of the estimated data and their representation.

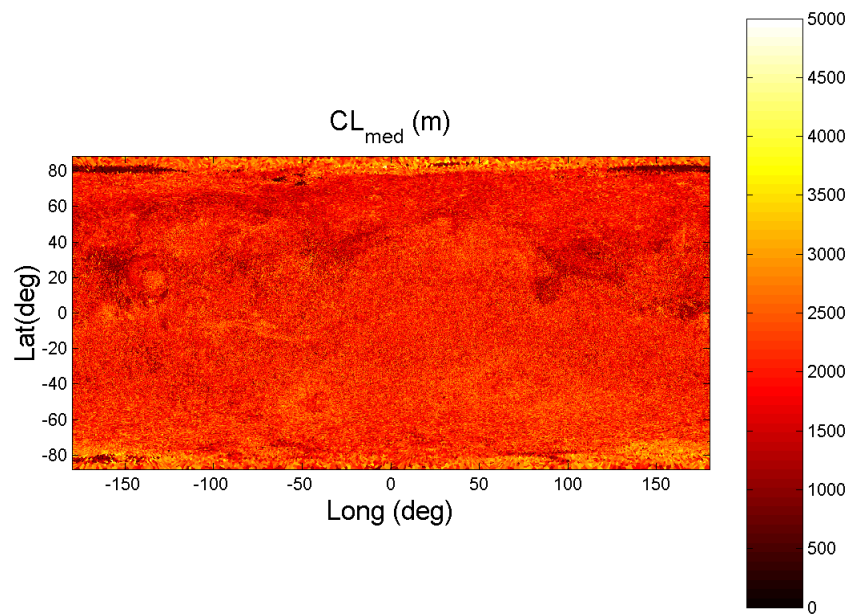


Fig. 4

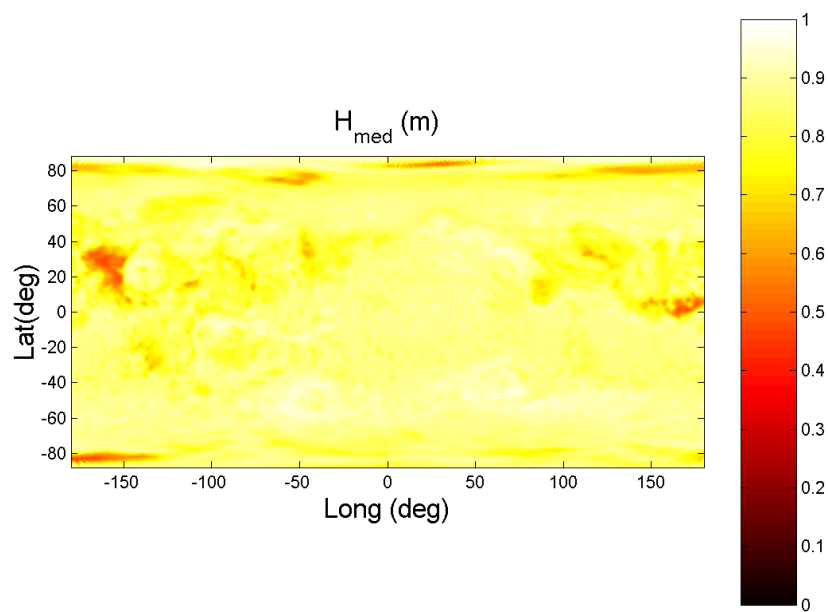


Fig. 5



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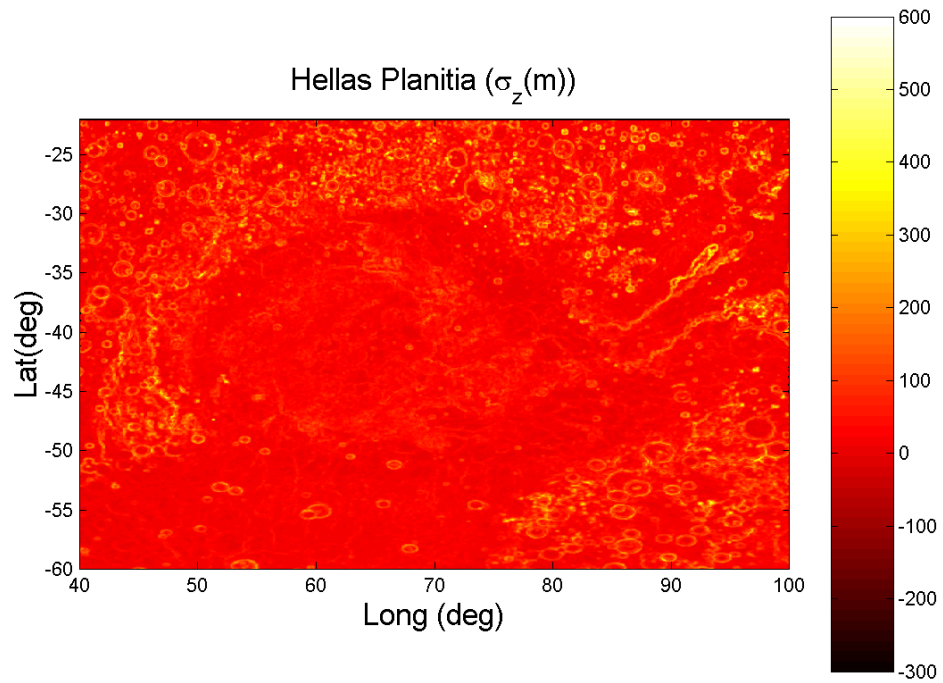


Fig. 6

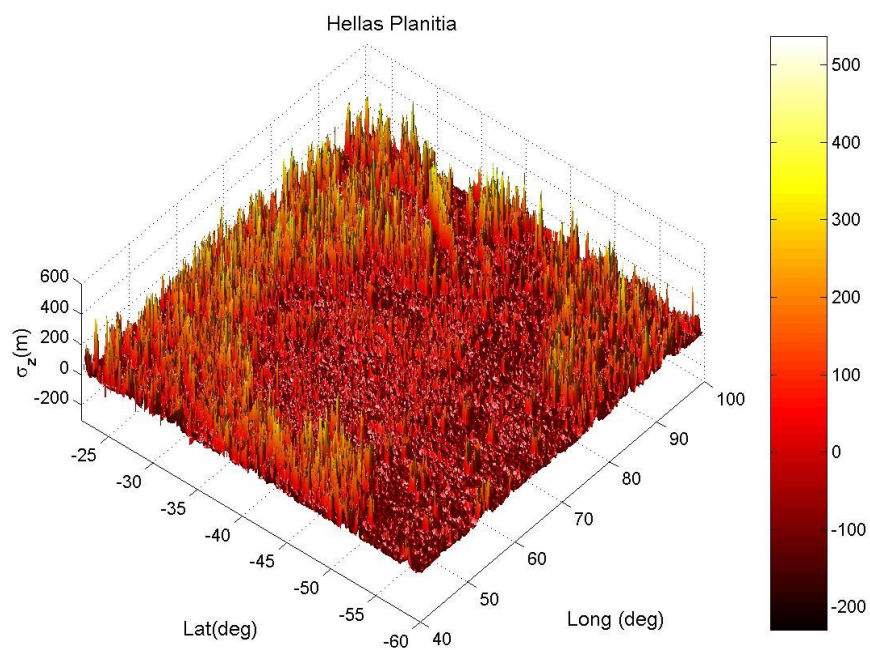


Fig. 7



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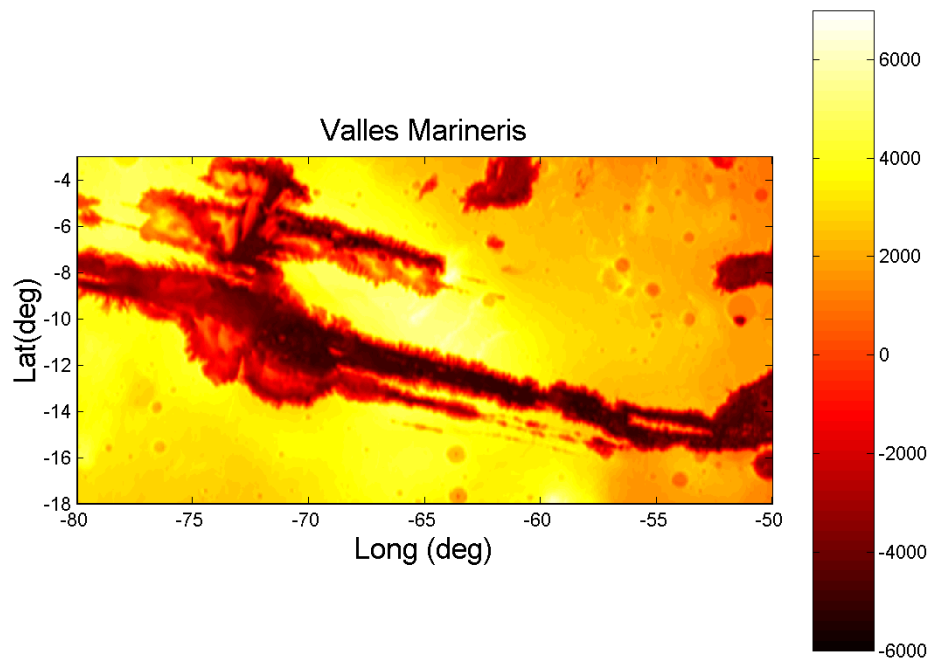


Fig. 8



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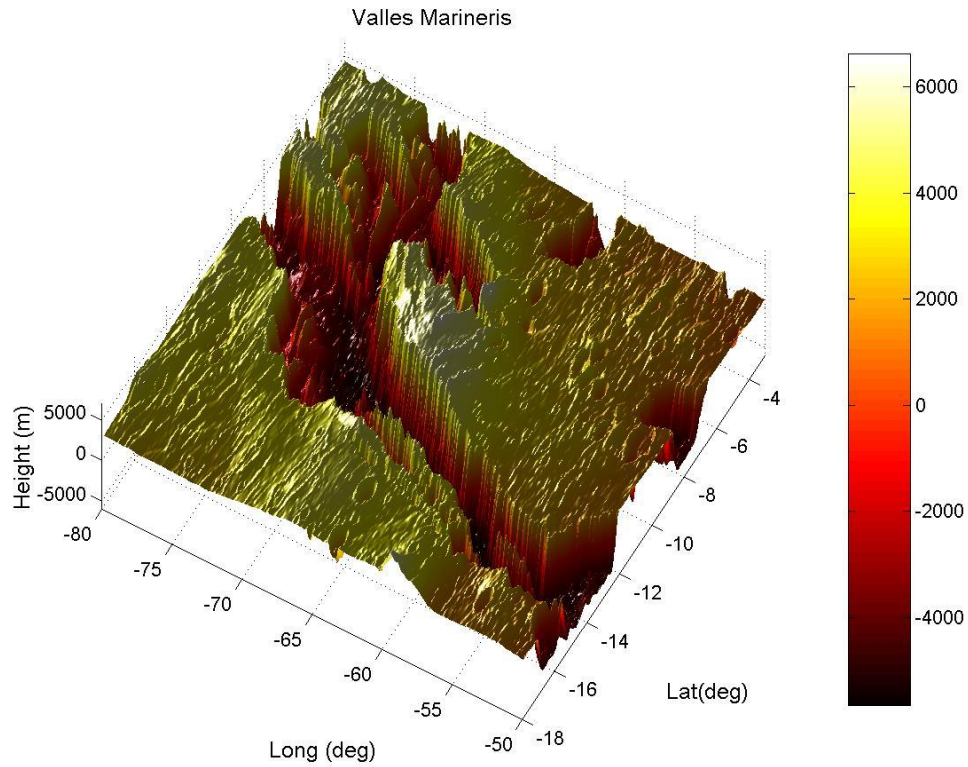


Fig. 9

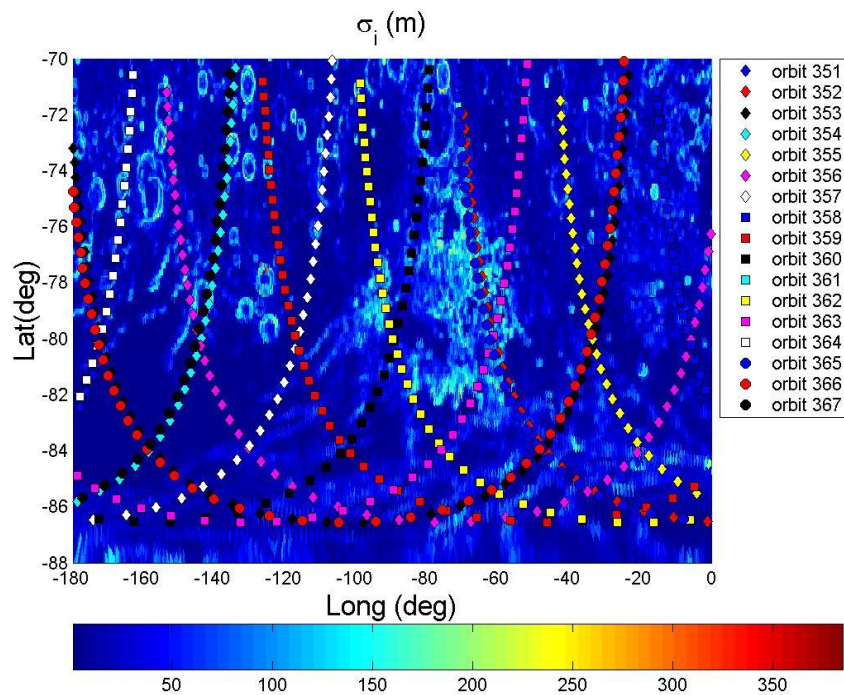


Fig. 10
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$5 \text{ m} \leq \sigma_i < 19 \text{ m}$ (light blue), $19 \text{ m} \leq \sigma_i < 25 \text{ m}$ (yellow), $25 \text{ m} \leq \sigma_i < 42 \text{ m}$ (red), $\sigma_i \geq 42 \text{ m}$

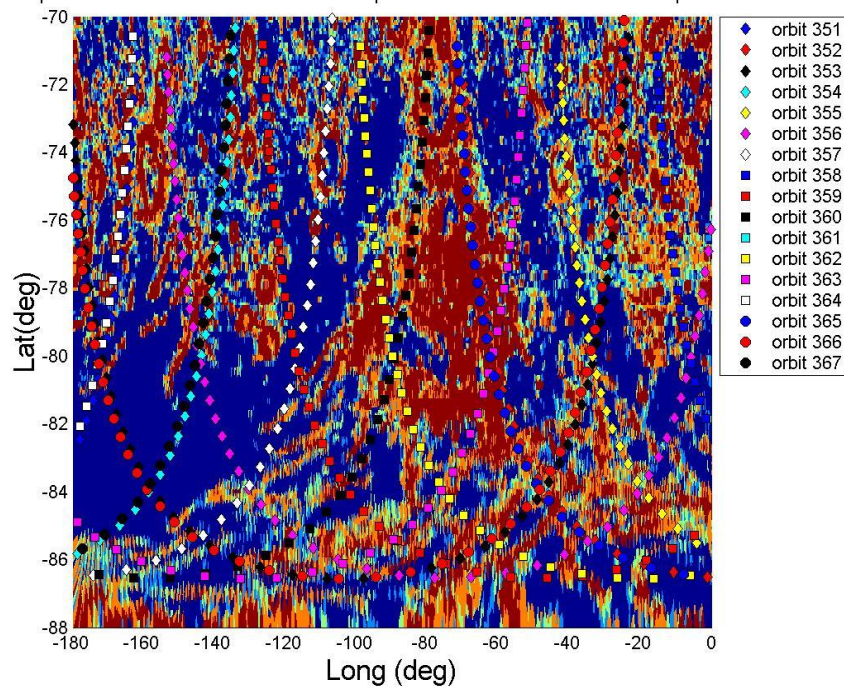


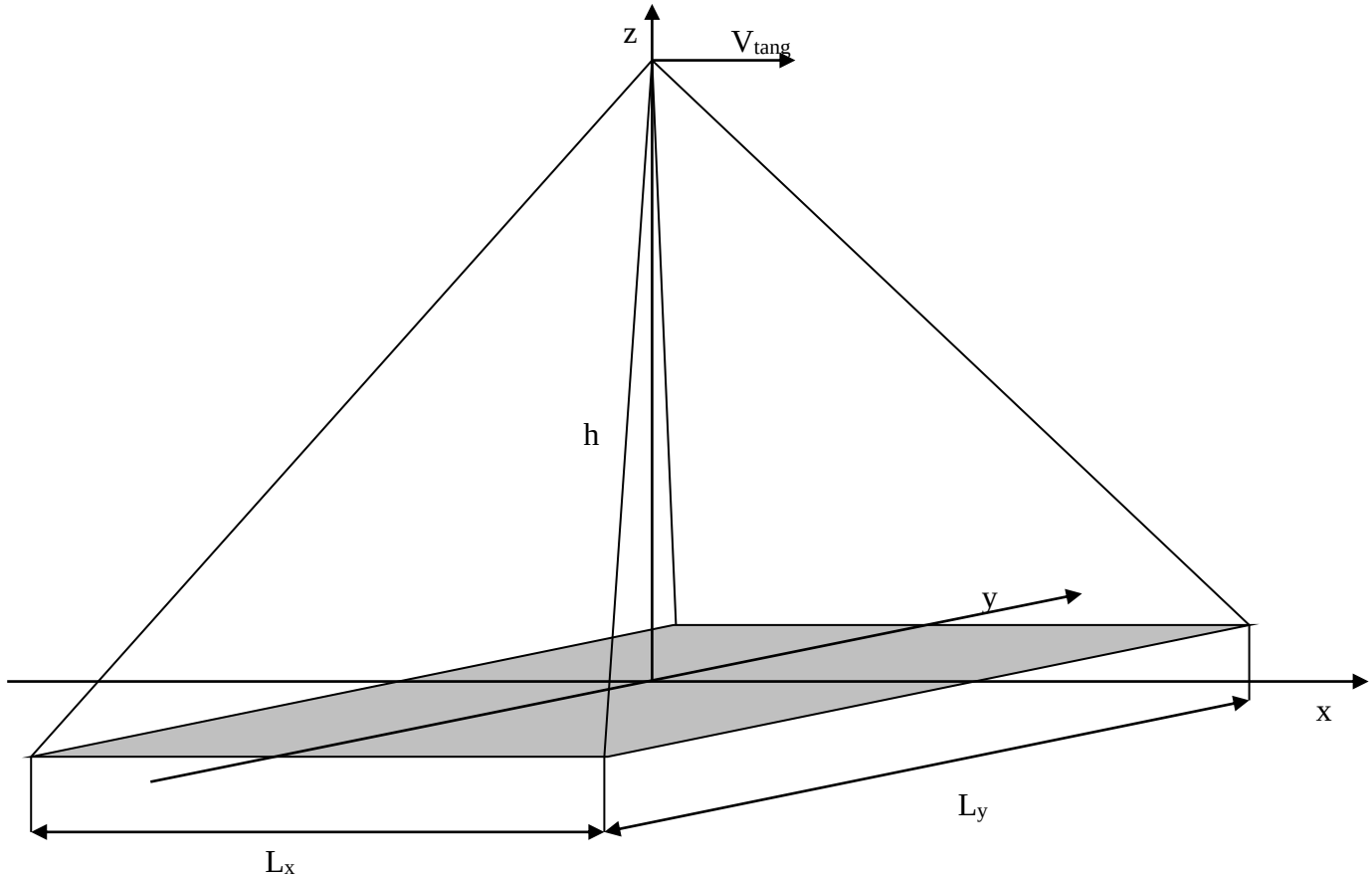
Fig. 11



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Appendix 3

A3.1 Radar Swath



$$L_x = 2\sqrt{2hr_d}$$

$$L_y = \sqrt{\frac{ch}{2f_{0\min}}} + \frac{N_0 V_{Tang}}{PRF} \quad \text{if } L_y < 5500m \rightarrow L_y = 5500m$$

h = S/C height

r_d = range resolution = 150 m

PRF = Pulse Repetition Frequency = 127.267 Hz

N_0 = 36/PRF

V_{Tang} = S/C tangential velocity

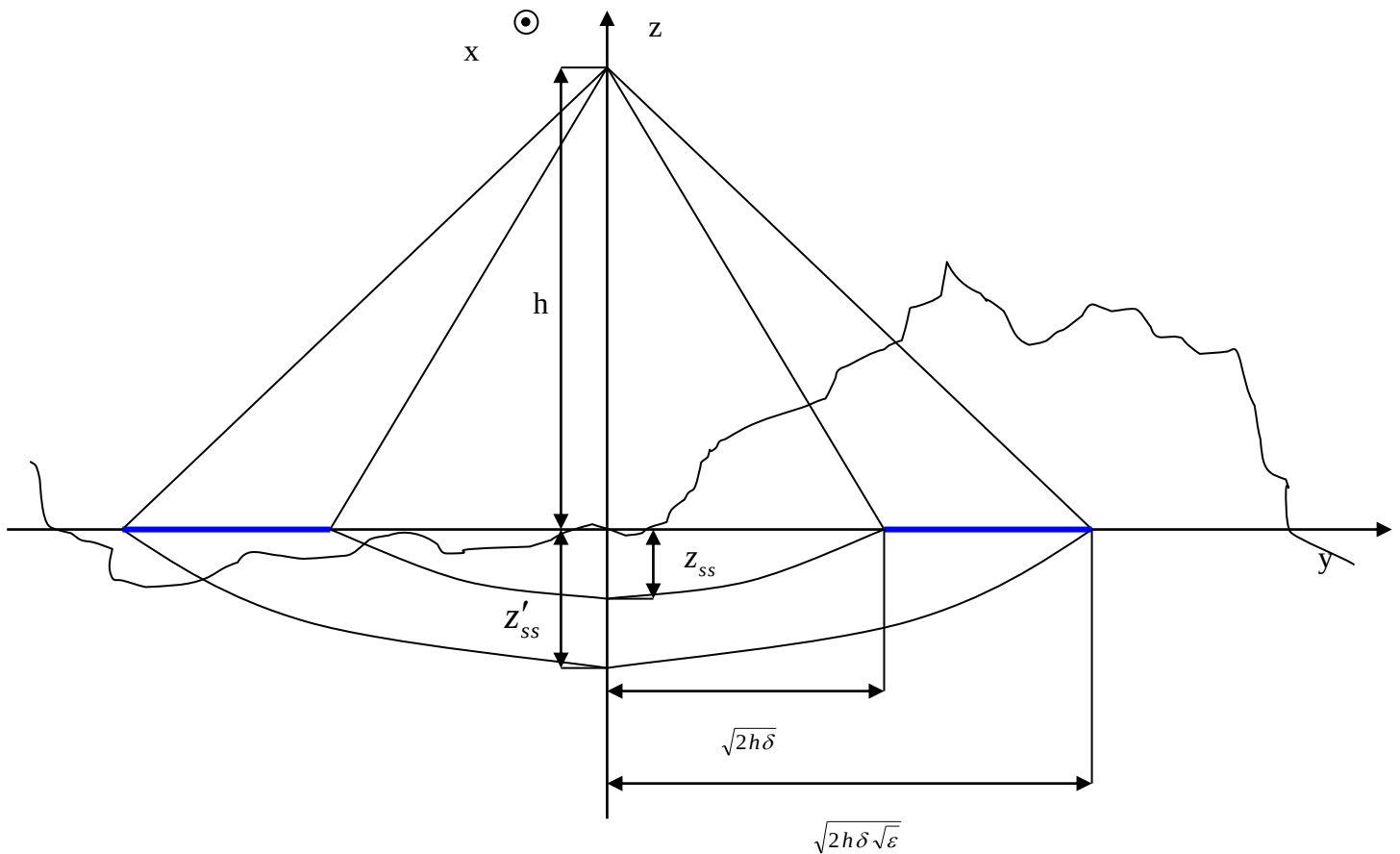
c = $3 \cdot 10^8$ m/s

$f_{0\min}$ = minimum frequency in use (when the Operative mode use only a frequency $f_{0\min} = f_0$)



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A3.2 Clutter analysis



x = along track direction

y = cross track direction

$$z'_{ss} = \delta$$

$$z_{ss} = \frac{\delta}{\sqrt{\epsilon}}$$

h = S/C height

δ = penetration depth = input

ϵ = real part of the dielectric constant of the subsurface material = input

The features described in A3.1 and A3.2 are performed by the GVT starting from the maps produced with the parameters available in the PCADB and also with the heights coming from the MOLA data. Is requested, in particular, to the GVT to show the results with maps 2D and 3D. In the latter case the GVT allows to the operator, to change the angle of visual.

Furthermore, the user can extract selected profiles from the maps described above.



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