# *TRAINING SESSION*

# *BRIGHTNESS TEMPERATURES PRODUCTS VISUALISATION*

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## I- OBJECTIVE

The objective of this session is to present the SMOS swath based brightness temperature product content trough exercises using interactive visualization and simple analysis.

## II – MATERIALS

### DATA

The main product used in the session is the:

**- SCLF1C/ SCSF1C:** SMOS swath based brightness temperature, full polarization product. The product is semi-orbit based. The gridding system is the ISEA grid (Icosahedral Snyder Equal Area) of 15km resolution. Each product is made of a header (xml format) and a data block (Binx format). (L1ProdSpec document page 293- 308).

Dual polarization products have been acquired at the beginning of the mission over periods of 15 days and for 5 months. Those products are named: SCLD1C/SCS1C. They are not presented here and can be considered as a particular case of the full polarization product (L1ProdSpec document page 268- 293).

### TOOLS AND SOFTWARES

- **VISAT – BEAM - BEAM 4.10.3**: BEAM is an open-source toolbox and development platform for viewing, analyzing and processing of remote sensing raster data developed by Brockmann-Consult for the European Space Agency (ESA).
  Download from: http://www.brockmann-consult.de/cms/web/beam/software
  Installation is user-friendly straightforward button clicking
- **SMOS-BOX 2.2 Add-on for BEAM 4.10.x**
  This is an add-on for VISAT that enables users to open, analyses and extract SMOS products.
  Download from: http://www.brockmann-consult.de/cms/web/beam/software
  Installation is straightforward button clicking
- **Bash and matlab scripts**
- **Matlab xml_toolbox : provided with the tools**

### REFERENCE DOCUMENTS

**L1ATBD**: SO-DS-DME-L1PP-0011-SMOS_L1_Processor_Algorithm_Theoretical_Baseline_Definition_ATBD
Here you can understand how the product has been obtained.

**L1ProdSpec:** SO-TN-IDR-GS-0005_SMOS_Level_1_And_Auxiliary_Data_Products_Specifications_v5.23_2012-02-24
This is your reference for the product content.

**L1VIS** : SMOS_Training_TB_L1C_Visualisation_2012 : complementary slides to this presentation

**Beam Help:** Beam software help / manual : a very well documented reference on how to use Beam

## EXERCISE 1: OVERVIEW OF THE L1C BRIGHTNESS TEMPERATURE PRODUCT CONTENT

The L1C product has two parts a HDR file and a DBL file. The product content is described in the L1ProdSpec document page 268-308.

### -PRODUCTS NAMING

**SM_REPR_MIR_SCLF1C_20110915T015749_20110915T025107_504_001_5**

- **SMOS**
— **OPERATIONAL / REPROCESSING**
——— **MIRAS**
———— **SCientific**
————— **Land/Salinity**
—————— **Full polarization/Dual polarization**
——————— **Level 1C**
———————— **Start validity time tag in UTC**
————————— **End validity time tag in UTC**
—————————— **Processor version**
——————————— **Configuration file version**
———————————— **Processing center**

### -THE HEADER FILE

- Open the HDR file in a text editor: e.g.

gedit SM_REPR_MIR_SCLF1C_20110915T101810_20110915T111129_504_001_5.HDR

Explore the xml file:

- Start Beam interface (Fig. 1)
- Open the folowing BT product : SM_REPR_MIR_SCLF1C_20110915T101810_20110915T111129_504_001_5.DBL
- In the left panel ("Product view"), d ouble click on the "Metadata", you can now explore the HDR content easily (see Fig. 1 )
- Open the following node: Metadata > Variable_Header > Specific_Product_Header > Main_Info > Time_Info
- Check the Ascending_Flag tag
- Explore : Metadata > Variable_Header > Specific_Product_Header > List_of_Data_Sets
- In Data_set number 13, get the name of the input SC_F1B file.

The time tag of SCLF1C and for a given semi-orbit is different than the SC_F1B. So it is useful to use the header to find corresponding files.

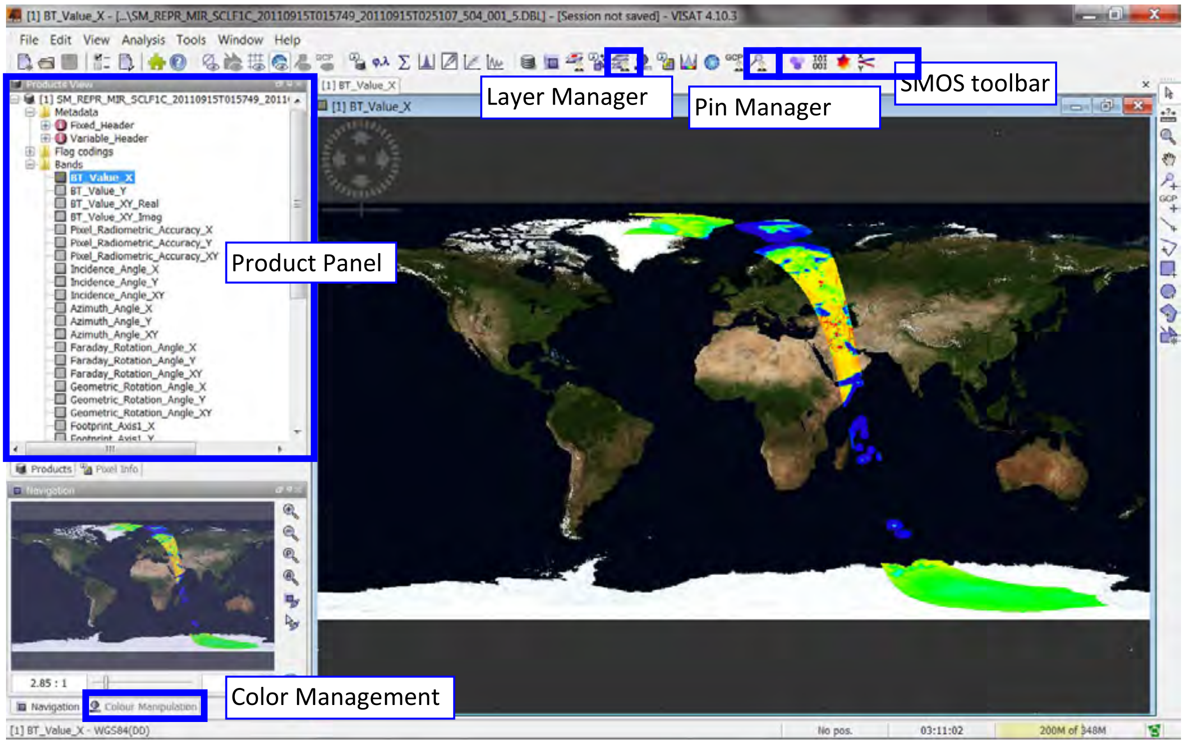



**Fig. 1 Screen capture of Beam interface (check Beam Visat manual for a complete description)**

- start matlab: matlab
- add xml_toolbox to path: addpath("XML_TOOLBOX_PATH")
- open xml file:

```
L1C_hdr=xml_load('SM_REPR_MIR_SCLF1C_20110915T015749_20110915T025107_504_001_5.HDR')
```

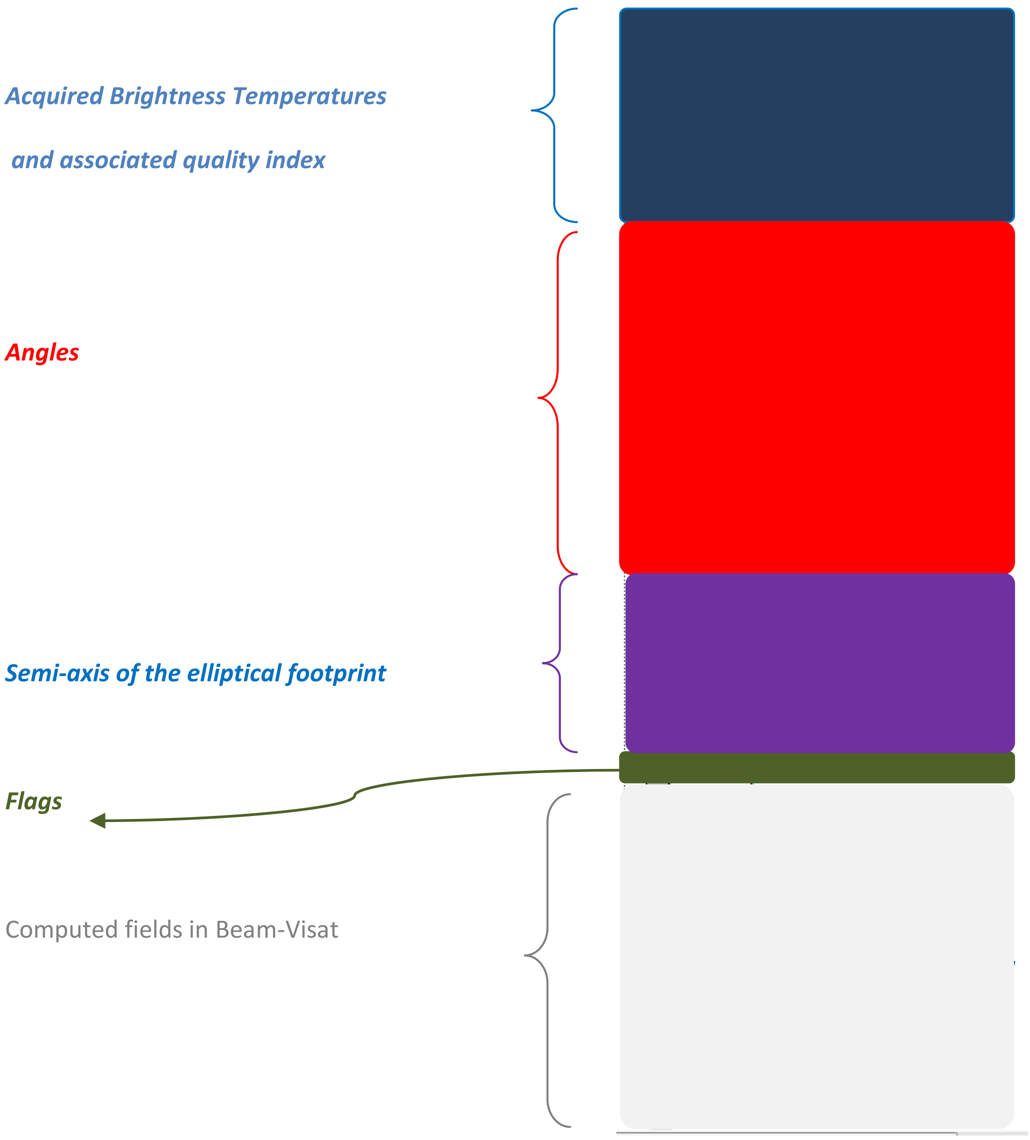
- extract tag:

```
L1B_file=L1C_hdr.Variable_Header.Specific_Product_Header.List_of_Data_Sets(13).Data_Set.Ref_Filename
```

## -THE DBL FILE

The DBL file contains the binary data these are presented in VISAT as "Bands". You can double click on any parameter to map it. The flags fields need to be decoded and mapping them before decoding is of no interest.

Notice that they are organized in snapshots and records in Binx format (see L1ProdSPec page 269). The snapshot information will be presented in Exercise 2. The fields in the product can be grouped as follows:




## EXERCISE 2: THE BRIGTNESS TEMPREATURES AT ANTENNA LEVEL

In this exercise the multi-angular brightness temperature acquisitions are mapped and interpreted with their associated uncertainties.

### -THE X,Y BRIGHTNESS TEMPERATURES

- map the BT_value_X by double clicking on the parameter in the Product left panel
- map the BT_value_Y
- in Navigation tab select the synchronize view
- zoom and check the product grid (ISEA 15km)

**About TBX @ 42.5°:** A browse product is plotted when the field is selected. This corresponds to brightness temperatures interpolated at 42.5° incidence angle, in the antenna reference frame (XY) in contrast to surface (HV) (see Exercise 3 & 4 for some information about XY vs HV, for complete information about XY HV see next training session).

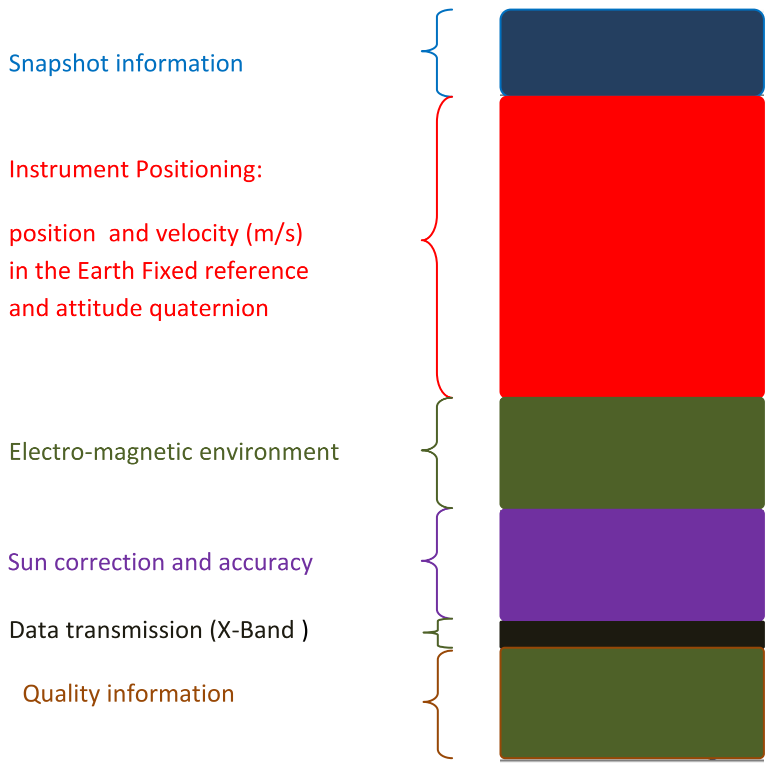
The brightness temperature is low (cold) on water surface and high on land surfaces. The brightness temperature can exceed physical values when polluting emissions exist (Radio Frequency Interference). The TBY is "generally" higher than TBX.

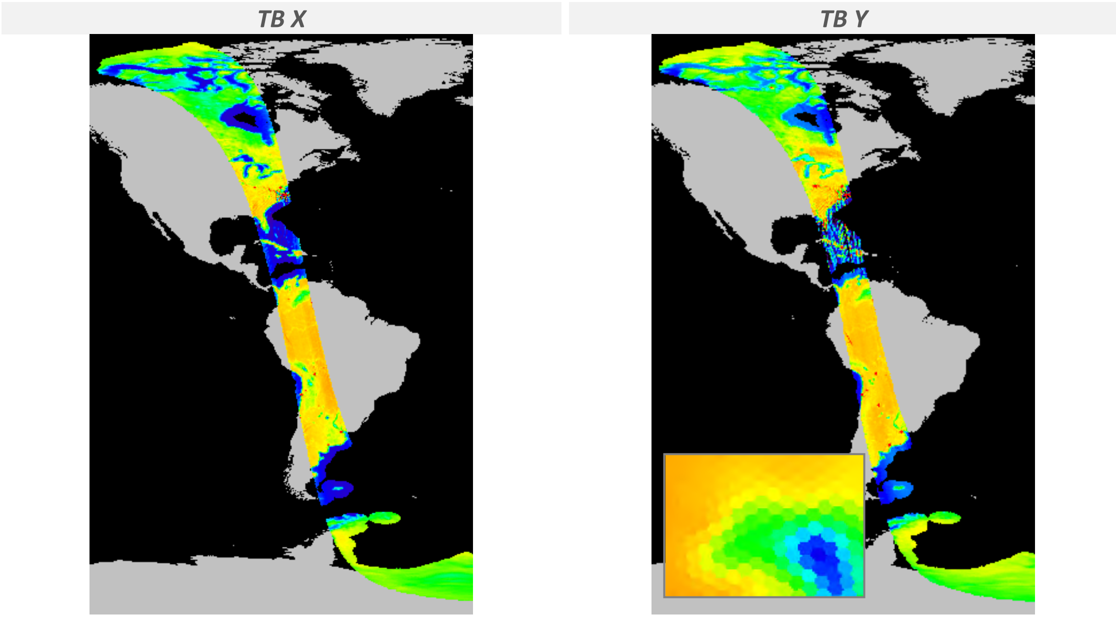
## -SNAPSHOT INFORMATION:

- in the SMOS Toolbox select Snapshot information tool
- select the synchronize with view and snapshot radio buttons
- slide cursor or increment slide number to select snapshoot

The snapshot id = Absolute_orbit_number*10000 + Seconds_from_ANX (ANX = Ascending Node)

The content shown by the snapshot can be grouped as follows:






**
*

**Fig. 2 X an Y polarization brightness temperatures acquisitions during ascending semi-orbit**

- slide cursor or increment Snapshot ID to select snapshoot
- map the BT_value_Y and slide cursor to change snapshot
- this is a “Land” product so values far from the coastlines are not displayed

- click on the Colour Manipulation icon: 
- modify the color range to 220-320 K, which is adapted for soil and vegetation surfaces

The SMOS acquisitions are snapshots with a roughly hexagonal shape. The snapshots are 1.2s away, so they overlap providing multi-angular brightness temperatures data with just one pass. Fig. 3 shows 3 samples of XX polarizations snapshots during an ascending semi-orbit. We use the SMOS Toolbox in order to inspect individual snapshots.

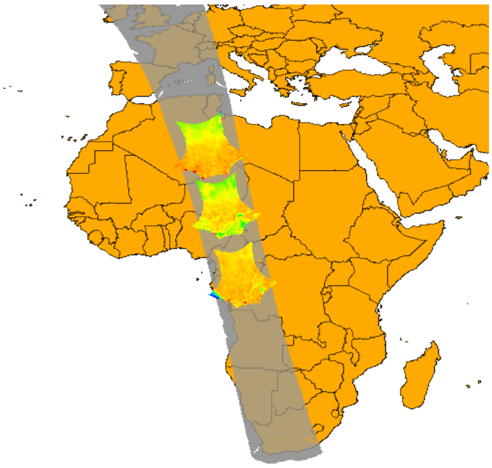


Fig. 3 Selected X polarization SMOS acquisitions during ascending semi-orbit.

## - RADIOMETRIC ACCURACY

- map Pixel_Radiometric_Accuracy_X
- map Pixel_Radiometric_Accuracy_Y
- Change the snapshot number while maintaining the Pixel_Radiometric_Accuracy_X
- Do the same for Pixel_Radiometric_Accuracy_Y

**About Pixel_Radiometric_Accuracy:** The pixel radiometric accuracy depends ontime interval of acquisition and incidence angle (see L1ATBD eq. 151 page 76). The incidence angles have the same distribution in each snapshot (as you will see in next exercise). It is the acquisition time that is creating high variability in the accuracy between two successive same polarization acquisitions. This is because when SMOS is acquiring full polarimetric data, cross polarization XY acquisition is done part of the integration time 0.4s of 1.2s is used to retrieve XX or YY polarization. The resulting XX and YY polarization is called un-pure as in contrast to the pure acquisition which is integrated over 1.2s (1 epoch).

Notice also that the number of snapshots is not incrementing uniformly. This is due to the acquisition sequence (see Table 1 )

Table 1 Acquisition sequence

| | | | |
|---|---|---|---|
| **XX** | **X XY** | **YY** | **Y YX** |

## - CROSS POLARIZATION

- map BT_Value_XY

**About Cross-polarization:** Cross polarization is mixed polarization X and Y acquisition. SMOS is acquiring full polarization acquisitions since end of commissioning (delivery) phase date. Dual polarization mode was tested during the first months of the mission.

➔ Check L1ATBD for more information

## EXERCISE 3: THE ANGLES

### - INCIDENCE ANGLE

- map Incidence_angle_X parameter

**About Incidence angle:** SMOS makes multi-angle acquisitions, and the incidence angles vary from 0 to 66.5 across the snapshot .

### - AZIMUTH ANGLE

- map the Azimuth_angle_X

**About azimuth angle:** This is the angle with the geographic coordinates. Notice the 180 and 0 degrees directions. This angle is used when projecting the synthetic antenna footprint on the surface (see Exercise 3)

### -FARADAY ANGLE & GEOMETRIC ANGLE

- Map the Faraday angle_X
- Map the geometric angle_X

**About Faraday angle and geometric angle:** They are mainly used to go from antenna reference frame (XY) to surface reference frame(HV) (follow next session XY HV TB, to learn how this is done).

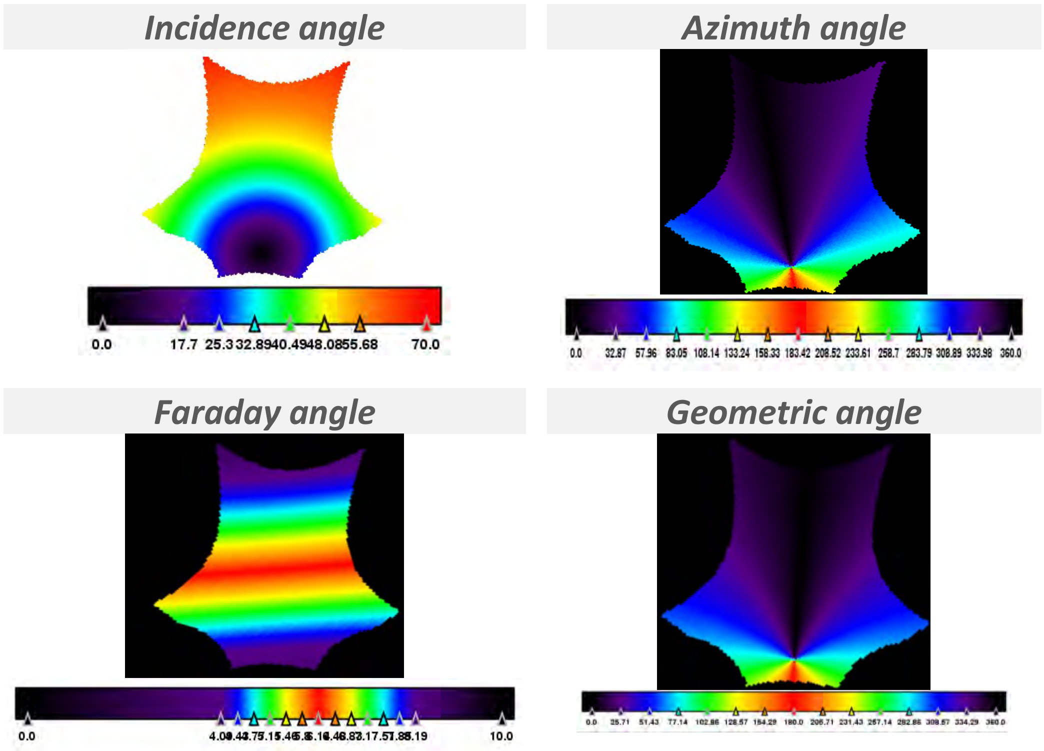


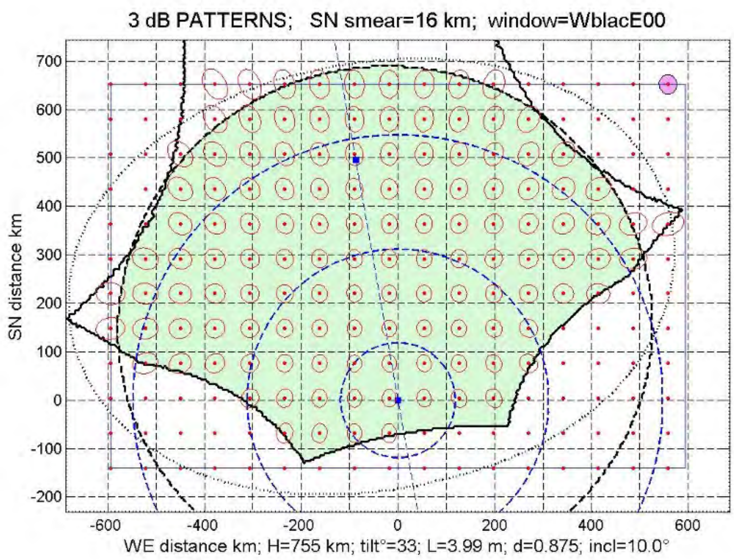

**Fig. 4 Variation of incidence azimuth faraday and geometric angles across a snapshot**

## EXERCISE 3: SYNTHETIC ANTENNA PATERN & RESOLUTION

- map Footprint_axis_1_X
- map Footprint_axis_2_X
- Select pixel info  and check the values of Footprint_axis_1_X and Footprint_axis_2_X

**About Footprint axis and resolutions:** The footprint_axis_1 and footprint_axis_2 correspond to the major and minor axis of the elliptical shaped synthetic antenna footprint. Notice that as we go further from the center of the snapshot their values increase. This means that resolution is decreasing. So the resolution is angle dependent. This is why we speak about nominal resolution.

**More about the antenna footprint:** We mean by this: the equivalent synthetic antenna pointing at the node position. The ellipsoid limits correspond to the 3db noise reduction level, which is equivalent to the limit where the noise to signal ratio is 0.5 (see L2ATBD page). Since the pointing direction is different across the snapshot the azimuth angle is needed to project the ellipsoid on the surface and compute the antenna weighting function.



Footprint axis 1 | Footprint axis 2

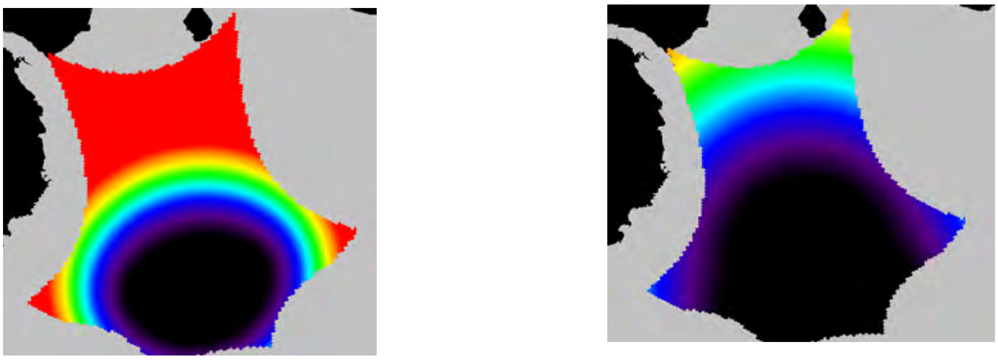


**Fig. 5 Variation of major footprint axis and minor footprint axis in (km) across a snapshot**

## EXERCISE 4: THE ANGULAR SIGNATURE

In this exercise we check the SMOS multi-angle signature over various surface types:

### -BRIGHTNESS TEMPERATURE PROFILES

- open product SM_REPR_MIR_SCLF1C_20110915T074810_20110915T084123_504_001_5
- map BT_Value_X and BT_Value_Y
- from SMOS Tool box  > select Snapshot information tool 
- go to snapshot ID: “98173382” in Australia.
- from SMOS Tool box  >select Grid point Tb 

A profile plot is obtained. It updates dynamically as you move in the product. It shows the TB X, TB Y and TB XY imaginary and real parts in a secondary axis. The TBs are plotted with their respective accuracy.

- go to the center of the snapshot: compare TB values for low and high incidence angles.
- go from the extreme left to the center of the snapshot: How is the incidence angle range changing, where is it the largest ?
- go across the snapshot. At what incidence angle the BTX and TBY cross, and why?

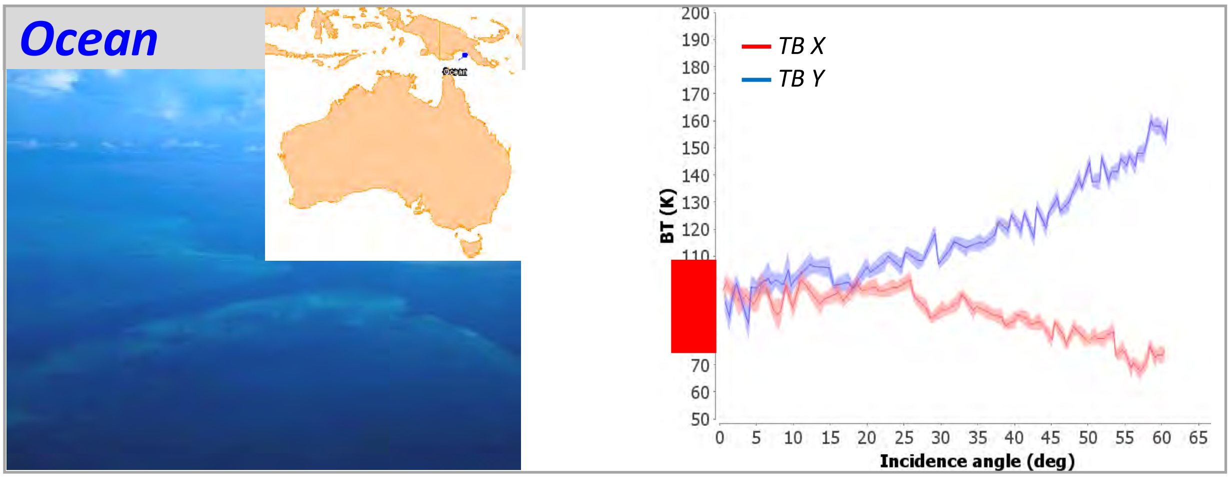
**About brightness temperature profiles:** The angle profile plots the X Y profiles at <u>antenna reference frame</u>, but the one that is useful for analysis is TB H and TB V at surface. The TBX and TBY are useful if Radiative transfer modeling is propagated up to the antenna reference frame, otherwise H-V should be used to compare with observed scene. Beam provides TB H and TB V but they are computed in a fast way, and profile plot is not provided for them. In the ext part of this exercise, we use grid points where TB(X,Y) ≈ TB(H,V) (see Exercise 2)

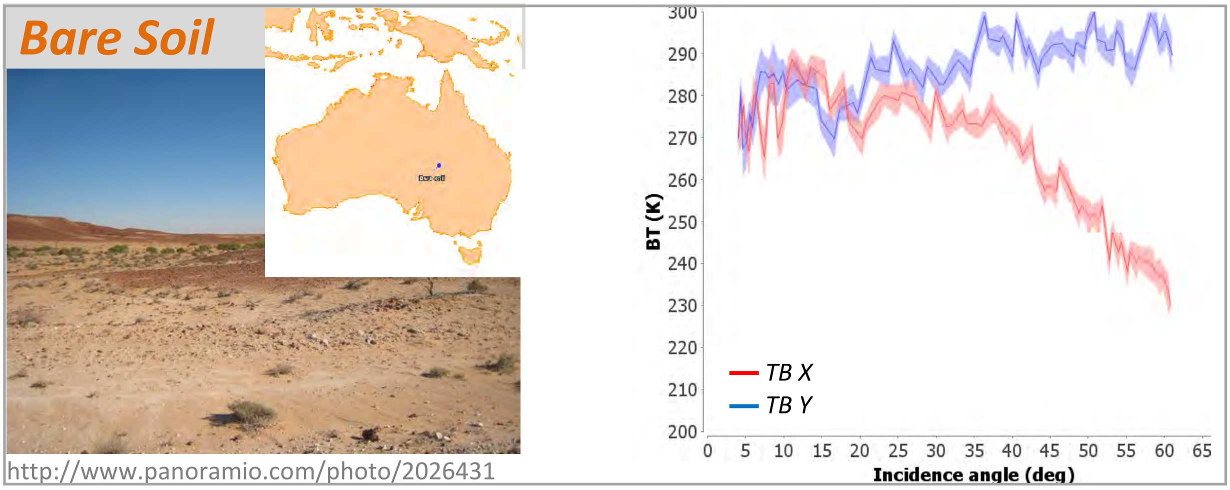
## - ANGULAR SIGNATURE OF VARIOUS SURFACE TYPES

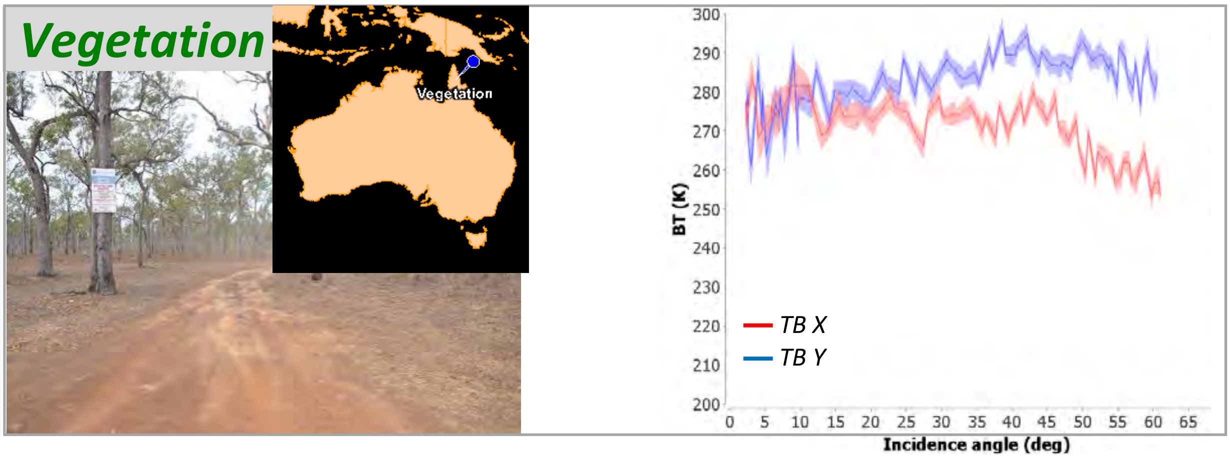
Here we compare the TB X and Y across different surface types.

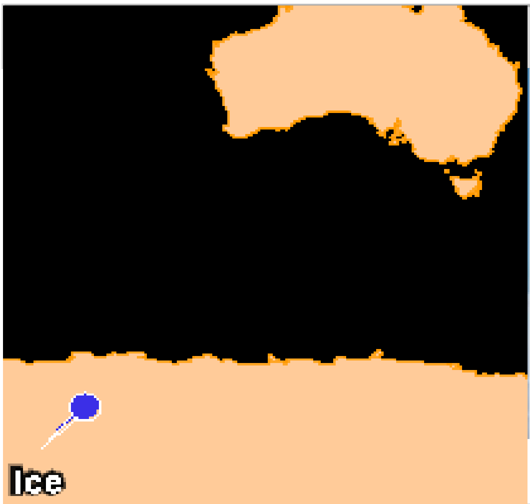
- open pin manager > select import pins > change file type to txt > open "smos_TB_pins.txt"
- open pixel info and verify that low polarization mixing is present at each pin.
- from SMOS Tool box >select Grid point Tb
- select "Snap to selected pin" in the bottom left of the profile plot
- from the map or using the pin manager window select a pin (1)
- right click on the image and save as image (2)
- repeat steps (1 and 2 ) for all the pins (you can also use the figure below in this document)
- compare the level of TB between Ocean water and all the other profiles
- compare the difference between TBX and TB Y in the Bare soil and vegetation profiles
- compare ice/snow and bare soil level
- for the coast zoom to the pin in the map and check the TB spatial variation at the coast
- Compare difference between TBX and TBY for topography and forest surface.

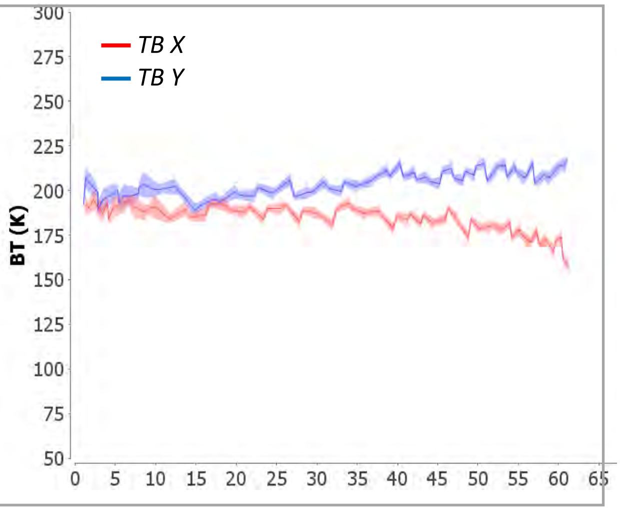
**About Angular signature:** The figures below show the obtained profiles for the different surfaces with a web image taken in the region and representative of the site (Thanks to the people who posted the images at panoramio).


Ocean
TB X
TB Y
BT (K)
Incidence angle (deg)

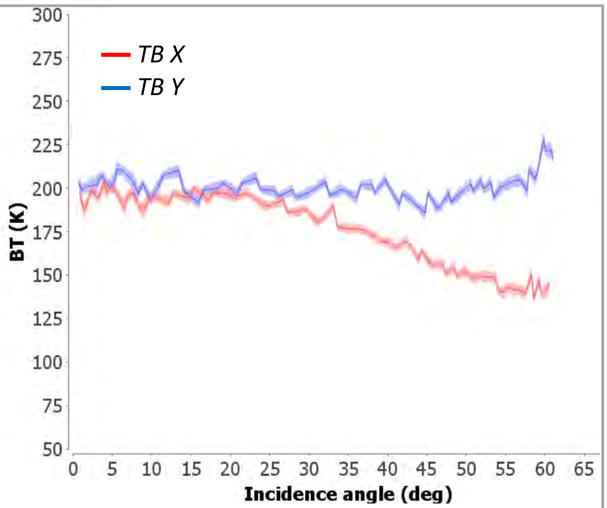

Bare Soil
http://www.panoramio.com/photo/2026431
TB X
TB Y
BT (K)
Incidence angle (deg)


Vegetation
Vegetation
TB X
TB Y
BT (K)
Incidence angle (deg)



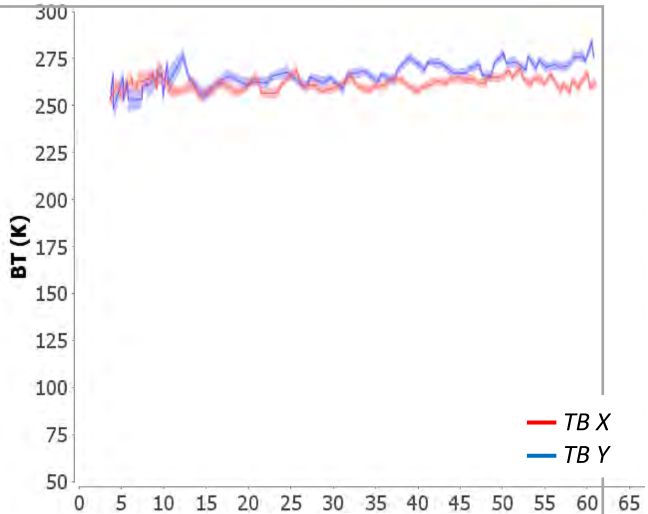




## Coast


http://www.panoramio.com/photo/8082155

## Topography / Forest


http://www.panoramio.com/photo/15347195

## EXERCISE 5: THE FLAGS

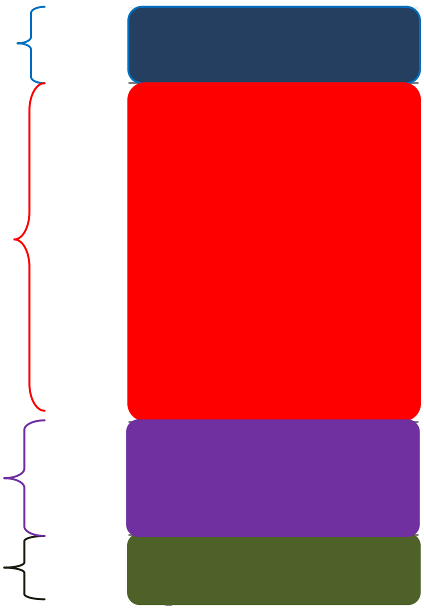
The BT product flags can be grouped as follows (see L1CProcSpec page 290):

Polarization flag:

Scene Corrections:
- Sun FOV:  Direct Sun correction activate
- Sun Glint FOV:  Reflected Sun correction active
- Moon FOV:  Direct Moon correction active
- SINGLE_SNAPSHOT:  no cross polarization mixing
- SUN POINT: position for sun alias correction
- SUN TAILS: position for hexagonal alias directions corrections
- SUN GLINT_AREA:  sun reflection position
- MOON POINT:  position for moon alias correction

Field Of View description

RFI flagging



Flags can be explored in spatial extent in each snapshot as a mask (using mask manager ) and as grid point information over all acquisitions for the semi-orbit using SMOS Box >flag matrix (**Fig. 6**)

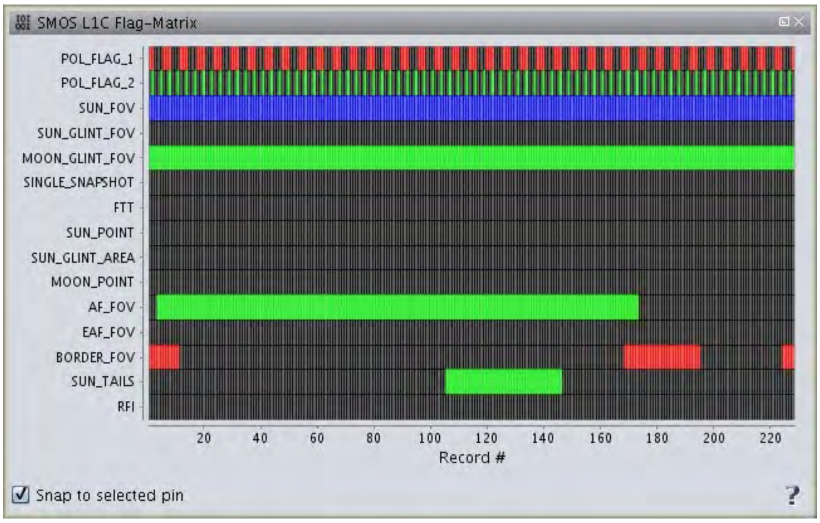



Fig. 6 Flags across TB records in the Beam SMOS Box Flag matrix view

### - POLARISATION FLAGS

- in SMOS Tool  select the flag matrix  (see Figure 6)
- Go to the edge of the snapshot where there is little records

- Analyse the Pol_Flag_1 and Pol_Flag_2
- Click on the L1C table icon
- Compare the polarization flag with the L1C table, keeping in mind the acquisition sequence in Table 1 (Exercise 2).

**Note: In mask manager (spatial view)** Beam doesn't decode well polarization flag. The polarization flag 1 is relevant to X and Y polarization, the polarization flag 2 is for cross-polarization or co-polarization. You will learn more about this flag in the next session. In flag matrix view the flag is well decoded.

## -FIELD OF VIEW DESCRIPTION FLAGS

- Open mask manager
- Activate alias free field of view AF_FOV and Border_FOV flags

**About Alias free area:** It is important to know that for soil moisture retrievals in the next level of the chain, the retrieval is not done using the complete snapshot area. It is done over a fraction of the surface. See L2ATBD to see this is filtered.

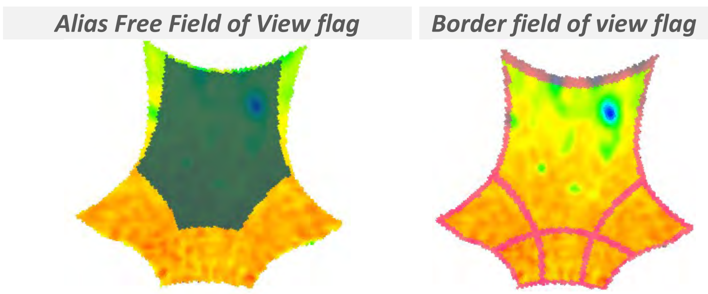



**Fig. 7 AF_FOV and Border_FOV flags**

## -SCENE CORRECTION FLAGS (SUN/MOON)

External sources like Sun and Moon need to be corrected in the image construction. This is done by removing their contribution. The correction flags indicated the grid node impacted by this correction.

- Open SM_REPR_MIR_SCLF1C_20110915T074810_20110915T084123_504_001_5
- from SMOS Tool box > select Snapshot information tool
- change Snapshot ID until over Australia
- Open mask manager
- Activate SUN_point and SUN_tails flags

**About sun tails:** the tails correspond to the directions of the antenna principal directions where the sun correction is propagated.

**More details:** The sun is a strong source and it impact the entire field of view, but in the direction of the secondary lobes its impact is more relevant, hence the flag.. This correction is needed because of the Gibbs effect. Notice we can see also those directions in the BT values in the case of strong RFI which is a also a strong point source.

- For moon flag:

- Open SM_REPR_MIR_SCLF1C_20110915T101810_20110915T111129_504_001_5.DBL
- from SMOS Tool box  > select Snapshot information tool 
- go to Snapshot:"98185896" in South America
- Activate Moon_Flag

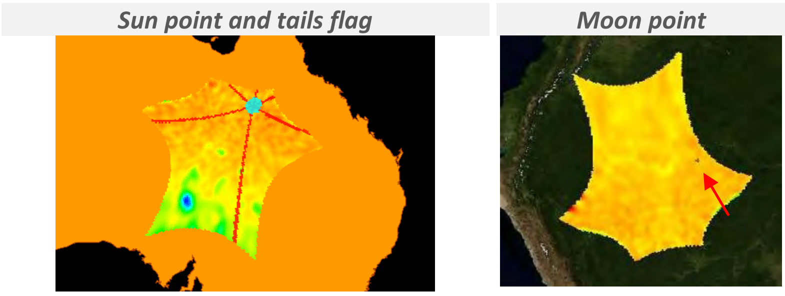



**Fig. 8 Sun point sun tails flag and moon point flag**

## -RFI FLAGS

(see next exercise)

## EXERCISE 6: RADIO FREQUENCY INTERFERENCE (RFI)

Types of sources: Sources as seen by SMOS (integration time, rotating radars, point source, antenna patterns)

RFI impact on the FOV (Point Spread Function with simulated RFI, theoretic impact on all points, decreasing threshold)

### - VISUALIZING THE RFI EFFECT

- Open product SM_REPR_MIR_SCLF1C_20110915T101810_20110915T111129_504_001_5.DBL
- Open BT_Value_X
- Inspect presence of RFIs in the browse visualization
- From the SMOS Box >select
- select the synchronize with view and snapshot radio buttons
- Change Snapshot ID to go to the northern part of South America (e.g. Snapshot ID: 98190161)
- use slider to increase snapshot number

Notice that few snapshots later the tails of a RFI are present

- Continue. See the effect of the RFI as the satellite moves away
- Do the same for BT_Value_Y

Compare what is visible in BEAM with what is happening in the Field Of View (L1VIS presentation).

### - RFI FLAGS

- Open product SM_REPR_MIR_SCLF1C_20110915T015749_20110915T025107_504_001_5.DBL
- Open BT_Value_X
- Open Snapshot visualization and go to snapshot ID: “98140000”

In the following snapshots (160-170 snapshots later) the tails of a faraway source are visible.

- Go further (e.g. 98140312) a clear non-punctual source is visible near Bahrein.
- Go further (e.g. 98140389) there are 3 strong sources which are quite close to one another
- in Color Management > Modify the color palette to distinguish the three maxima (hint: a maximum BT of 3000 K will help you)
- With the Pixel Information box give an approximate location for the 3 sources (3 airfields near the sources).

Notice that the RFI flag (in the flag matrix window) is never ON.

- Using Tools > Create Band with Band Maths > create a new band, with the expression (if Flag_RFI_2, then NaN, else BT_Value_X). “Edit expression” -> “Operators” -> select the first choice. Write “Flag_RFI_2 ? NaN : BT_Value_X” selecting the bands on the left.
- in color management > Change the colors for the new band.

Notice that this flag is raised.

- Go on with the snapshots. Notice all the maxima that were flagged.

## - RFI CARACTERISATION

- Open product SM_REPR_MIR_SCLF1C_20100701T094401_20100701T103721_504_801_5.DBL (in the Session Folder)
- Open BT_Value_X
- This SCLF1C product was cut using (see cut_L1C.m in tools )so that only the region surrounding Puerto Rico remains

With the snapshot visualization , notice that the source is emitting every 24 seconds.

- In the mask manager activate the Flag_RFI_2 mask

Notice that the flag is never raised in this cut. Nevertheless it is easy to identify the corrupted snapshots and avoid them if needed.

## EXERCISE 7: EXTRACTING DATA

In this exercise data extraction using Beam is presented. Beam is very efficient in cpu time and memory consumption in extracting the data over regions of interest. Nevertheless it is highly recommended to put (or link) in the product directory only the products where the region of interest is visited. In fact SMOS swath based data files are numerous: about ~10440 product per year and product type.

### -EXTRACTING USING BEAM INTERFACE

#### -EXTRACTING RECORDS FOR A DGG FROM ONE PRODUCT

- Open product
- Add a pin and select it
- Select > select data table
- Select snap to selected pin in data table
- Select export > write to file SMOS L1C Table.txt
- Copy plot_beamL1C_table.m to file directory and Open matlab
- run plot_beamL1C_table
- check the D.colheaders

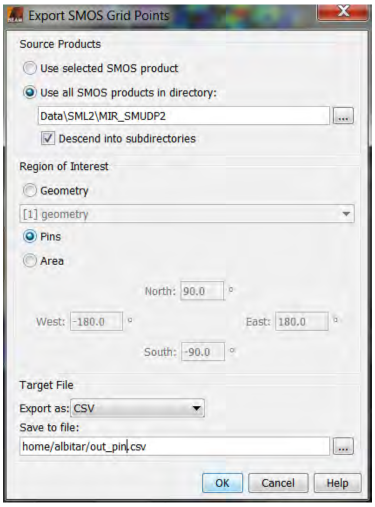
SMOS L1C Table

| Rec# | Flags | BT_Value_Real | BT_Value_Imag | Pixel_Radio... |
|---|---|---|---|---|
| 1 | 4101 | 285.723 | 0 | 4.125 |
| 2 | 4103 | -12.289 | 5.521 | 3.471 |
| 3 | 4100 | 243.297 | 0 | 2.448 |
| 4 | 5124 | 247.33 | 0 | 3.94 |
| 5 | 5126 | -12.858 | 2.541 | 3.365 |
| 6 | 5125 | 301.624 | 0 | 2.546 |
| 7 | 5125 | 304.308 | 0 | 4.097 |
| 8 | 5127 | -9.758 | -1.134 | 3.448 |
| 9 | 5124 | 244.814 | 0 | 2.433 |
| 10 | 5124 | 243.542 | 0 | 3.915 |
| 11 | 5126 | -5.109 | -0.98 | 3.343 |
| 12 | 5125 | 294.312 | 0 | 2.529 |
| 13 | 1029 | 293.917 | 0 | 4.07 |
| 14 | 1031 | -5.569 | 0.071 | 3.426 |
| 15 | 1028 | 250.339 | 0 | 2.416 |
| 16 | 1028 | 250.955 | 0 | 3.889 |
| 17 | 1030 | -1.404 | 2.473 | 3.319 |
| 18 | 1029 | 294.979 | 0 | 2.51 |
| 19 | 1029 | 292.394 | 0 | 4.038 |
| 20 | 1031 | 0.527 | -4.028 | 3.401 |
| 21 | 1028 | 250 | 0 | 2.4 |
| 22 | 1028 | 252.802 | 0 | 3.862 |
| 23 | 1030 | -2.245 | -1.232 | 3.296 |
| 24 | 1029 | 290.437 | 0 | 2.493 |
| 25 | 1029 | 289.154 | 0 | 4.012 |
| 26 | 1031 | -5.722 | -7.437 | 3.379 |
| 27 | 1028 | 248.829 | 0 | 2.383 |
| 28 | 1028 | 253.52 | 0 | 3.835 |
| 29 | 1030 | -8.017 | -8.688 | 3.274 |
| 30 | 1029 | 291.579 | 0 | 2.479 |
| 31 | 1029 | 293.104 | 0 | 3.989 |
| 32 | 1031 | -6.146 | 0.787 | 3.358 |

Snap to selected pin  Columns...  Export...  ?

#### -EXTRACTING OVER REGION OF INTEREST OR PINS IN SEVERAL FILES

- construct your region of interest:
  - use the geometry tools
  - add pins or import pins
- extract the data :
  - select Tools > Export SMOS Gird Points
  - select "use all smos products in directory"
  - input root folder for L1C data
  - select Descend into subdirectories
  - fill Region of interest information
  - Input the output filename




Analyses of the extracted file will be presented in the next session (see XY2HV_Beam.m)

Note: The extraction will take into consideration all readable SMOS products. So make sure only desired type of product is in the sub-diectories. If the number of files is high (complete SMOS dataset over more than one year), then you need to divide the extraction into smaller (monthly) parts. The best is to use command line extraction in this case.

## - COMMAND LINE EXTRACTION

As stated before, prior to extraction it is recommended to put (or link) in the product directory only the products where the ROI is visited. This will greatly reduce extraction time. Command line extraction is available for box area and one point of interest (lat lon) at a time (in Beam interface see Help > Grid Point Export)

- to extract over lon and lat, open terminal and enter

```
${Beam_install_dir}/bin/export-grid-points.sh -box 75.0 77.0  10.0 12.0 -o extract.csv  SM_????_MIR_SCSF1C_*_9
```

- Beam will extract information

If the number of products is high, than use a monthly or daily loop for the extraction. For example if data is organized by year, month and day do

```
for iyear in "2011" "2012"
do
      for imonth in "01" "02" "03" "04" "05" "06" "07" "08" "09" "10" "11" "12"
      do
         ${Beam_install_dir}/bin/export-grid-points.sh -box 75.0 77.0  10.0 12.0  -box 75.0 77.0  10.0
12.0 -o    temp.csv        $iyear/$imonth/??/SM_OPER_MIR_SCLF1C_*
         cat temp.csv >> out.csv
       done
done
rm temp.csv
```

The obtained product will have this format :

```
# path_to_SMOS_product          #/mnt/MIR_SCF1C/2011/09/15/SM_REPR_MIR_SCLF1C_20110915T001742_20 ….
Header_containing_parameters    Grid_Point_ID;Latitude;Longitude;Altitude …
Extracted_data                  8165618;-24.617000579833984;141.94200134277344;192.1699981689453 ….
Extracted_data                  8165618;-24.617000579833984;141.94200134277344;192.1699981689453 ….
Empty_line                      8165618;-24.617000579833984;141.94200134277344;192.1699981689453 ….
.                               .
.                               .
.                               .
```

The Extracted_data will be empty if the node is not included in the product. To clean it and analyze it see next session (see XY2HV_Beam.m)

➔ More about extraction in the next session and the L2SM visualization session