INSTRUMENT COLLOCATION ANALYSIS TOOL – FILE TRANSFER DOCUMENT

1. INTRODUCTION

With the increasing number of flying Earth Observation missions, activities derived from the combination of data coming from instruments on different satellites have a growing potential. As a consequence of the increment in the number of missions, the opportunities of observations of the same area by different instruments within a limited time period also increase. The main question for the Earth Observation community would then be where and when these observation opportunities will take place.

Several software solutions exist to analyse the coverage for individual instruments. However the existing tools are not made to study the overlap between two instrument swaths in the same geographical region, with a certain time difference of interest. For these purposes, two tools were generated, namely InstrCollocationStats and InstrCollocationOpp:

1- InstrCollocationStats
   Calculates how frequent the collocation opportunities of interest are at all latitudes along the orbit. Also provides minimum and maximum time difference for the first revisit opportunity for each latitude in the orbit.
2- InstrCollocationOpp
   Receives a time window and a zone and returns specific details of all collocation opportunities within this window and within the zone of interest.

The maximum time difference of interest is always an input from the user and can vary from 1 minute to 1 year, according to the purpose of the study.

1.1 Purpose

Some examples of applications can be the following

1- Instrument calibration/validation:
   A new instrument may have to be calibrated/validated by comparing results with a similar instruments on different platforms. For this purpose, swath overlaps on the same area need to be identified and the time difference of interest will be small, depending on instrument characteristics.
2- Combination of different data sets:
   Data sets of different instruments covering the same geographical region could need to be used for modelling, monitoring or interferometry.
3- Revisit time study for mission design.
   Statistics of the revisit time for the coverage over a certain zone can be needed. For example, given the current configuration of S1A and S1B, the maximum revisit time will be 6 days, and will be less in some areas. This tool could be used to study how these numbers change as a function of S1B's orbital parameters.

1.2 Change History

Issue	Change Description
1.0	First issue
1.1	Package contents re-arranged - inputs/mission configuration files folder added - folder per platform
1.1.1	InstrCollocationOpp: End of time segment set to exit time instead of multiple of time step
1.1.2	Update *mission_configuration_files* folder to v1.5

1.3 Distribution List

Project/Unit	Name	Project/Unit	Name	Project/Unit	Name

1.4 Reference Documents

No reference documents.

2. ARCHIVE CONTENT

The following archive file has been delivered (generated with the zip utility):
`InstrCollocationTools_v1_1_2_date_11_JUN_2018.zip`

The archive contains the following files:

```
WINDOWS32/inputs/inputs_opp_portugal.txt
WINDOWS32/inputs/inputs_stats_s1_s1_example.txt
WINDOWS32/inputs/inputs_stats_s3_s2.txt
WINDOWS32/inputs/mission_configuration_files/…
WINDOWS32/InstrCollocationOpp.exe
WINDOWS32/InstrCollocationStats.exe
WINDOWS32/pthreadVC2.dll
WINDOWS32/pthreadVC2.lib
WINDOWS32/InstrCollocationStats.exe
WINDOWS32/outputs/kml/SENTINEL1A(SAR1EW)_SENTINEL1B(SAR1EW)__orbit_15495_15499.kml
WINDOWS32/outputs/kml/SENTINEL3(SLSTR_B)_SENTINEL2A(MSI)__orbit_15495_15499.kml
WINDOWS32/outputs/kml/
SENTINEL3(SLSTR_B)_SENTINEL2A(MSI)__SENTINEL2A_MSI__20160228T125402_20160415T145402.kml
WINDOWS32/outputs/kml/
SENTINEL3(SLSTR_B)_SENTINEL2A(MSI)__SENTINEL3_SLSTR_B__20160228T125402_20160415T145402.kml
WINDOWS32/outputs/txt/SENTINEL1A(SAR1EW)_SENTINEL1B(SAR1EW)__orbit_15495_15499.txt
WINDOWS32/outputs/txt/SENTINEL3(SLSTR_B)_SENTINEL2A(MSI)__orbit_15495_15499.txt
WINDOWS32/outputs/txt/SENTINEL3(SLSTR_B)_SENTINEL2A(MSI)__SENTINEL2A_MSI__20160228T125402_20
160415T145402.txt
WINDOWS32/outputs/txt/SENTINEL3(SLSTR_B)_SENTINEL2A(MSI)__SENTINEL3_SLSTR_B__20160228T125402
_20160415T145402.txt

MACIN64/inputs/…
MACIN64/InstrCollocationOpp
MACIN64/InstrCollocationStats
MACIN64/outputs/…

LINUX64/inputs/…
LINUX64/InstrCollocationOpp
LINUX64/InstrCollocationStats
LINUX64/outputs/…
```

3. ARCHIVE CONTENT DESCRIPTION

File	Description
WINDOWS32/pthreadVC2.dll WINDOWS32/pthreadVC2.lib	Auxiliary files for Windows
WINDOWS32/InstrCollocationStats.exe	Executable file
WINDOWS32/InstrCollocationOpp.exe	Executable file
WINDOWS32/inputs/inputs_opp_portugal.txt	Example of input configuration file for InstrCollocationOpp.exe
WINDOWS32/inputs/inputs_stats_s1_s1_example.txt	Example of input configuration file for InstrCollocationStats.exe
WINDOWS32/inputs/inputs_stats_s3_s2.txt	Example 2 of input configuration file for InstrCollocationStats.exe

WINDOWS32/inputs/mission_configuration_files/…	Input orbit files and swath files
WINDOWS32/inputs/zones/coast_portugal_spain.dbf	Zone file including Portugal coastline
WINDOWS32/outputs/txt/SENTINEL1A(SAR1EW)_SENTINEL1B(SAR1EW)__orbit_15495_15499.txt WINDOWS32/outputs/KML/SENTINEL1A(SAR1EW)_SENTINEL1B(SAR1EW)__orbit_15495_15499.kml	Example of output files for InstrCollocationStats.exe Example 1
WINDOWS32/outputs/txt/SENTINEL3(SLSTR_B)_SENTINEL2A(MSI)__orbit_15495_15499.txt WINDOWS32/outputs/KML/SENTINEL3(SLSTR_B)_SENTINEL2A(MSI)__orbit_15495_15499.kml	Example of output files for InstrCollocationStats.exe Example 2
WINDOWS/outputs/txt/SENTINEL3(SLSTR_B)_SENTINEL2A(MSI)__SENTINEL2A_MSI__20160228T125402_20160415T145402.txt WINDOWS/outputs/txt/SENTINEL3(SLSTR_B)_SENTINEL2A(MSI)__SENTINEL3_SLSTR_B__20160228T125402_20160415T145402.txt WINDOWS/outputs/KML/SENTINEL3(SLSTR_B)_SENTINEL2A(MSI)__SENTINEL2A_MSI__20160228T125402_20160415T145402.KML WINDOWS/outputs/KML/SENTINEL3(SLSTR_B)_SENTINEL2A(MSI)__SENTINEL3_SLSTR_B__20160228T125402_20160415T145402.KML	Example output files for InstrCollocationOpp.exe
MACIN64/… LINUX64/… LINUX64/…	Same files as for WINDOWS, but with the corresponding operating system versions

4. INSTALLATION

The archive can be expanded with the command unzip (in Linux/Mac Intel) or with Winzip / 7-zip (in MS Windows).

5. USAGE

5.1 Executable program *InstrCollocationStats*

This program receives the information of the satellite orbit and instrument swath characteristics, and three maximum time difference the user is interested in analysing. It calculates how frequent the collocation opportunities are at all latitudes along the orbit. Also provides minimum and maximum time difference for the first revisit opportunity.

5.1.1 Command line input parameters description

The command line parameters of the executable routine are the following (provided in the order in which they have to be supplied):

INPUT PARAMETERS	Definition	Value
Input Configuration File	Filename (it may include the path to the file)	Given by the user

5.1.2 Configuration file input parameters description

INPUT PARAMETERS	Definition	Value
SATELLITE 1		
Satellite	Satellite identifier	SENTINEL1A SENTINEL1B SENTINEL2A SENTINEL3A EARTHCARE METOP1 AEOLUS GENERIC
Orbit filename	Filename (it may include the path to the file)	

Swath ID	Swath ID of master satellite	
Swath filename	Filename (it may include the path to the file)	
SATELLITE 2		
Satellite	Satellite identifier	SENTINEL1A SENTINEL1B SENTINEL2A SENTINEL3A EARTHCARE METOP1 AEOLUS GENERIC
Orbit filename	Filename (it may include the path to the file)	
Swath ID	Swath ID of slave satellite	
Swath filename	Filename (it may include the path to the file)	
GENERAL		
Time step	Step for the simulation in seconds	
Start orbit	Integer indicating start master orbit for simulation	
Stop orbit (including)	Integer indicating stop master orbit for simulation	
Maximum overlap difference	Maximum time difference of interest in minutes	
Second overlap difference	Another maximum time difference of interest in minutes	
Third overlap difference	Another maximum time difference of interest in minutes	
KML FLAG	1- Write a KML file 0- Do not write a KML file	1 or 0
SCF FLAG	1- Write a SCF file 0- Do not write a SCF file	1 or 0

5.1.3 Algorithm

The program first reads the input configuration file, and initialises all the information according to the orbit and swath files. After this, the simulation is started.

Given that both satellites have a certain repeat cycle (RP1, RC2), this means that their relative geometry will have as a combined repeat cycle (CRC) the lowest common multiply between the two repeat cycles. This can sometimes be the multiplication of the two repeat cycles or even just one repeat cycle like when considering S1A-S1B. This is therefore the simulation period that is analysed.

The program first studies the swath of the master satellite for one orbit. It divides the ground swath of the master satellite's orbit into segments (with a time step specified by the user), as seen in figure 1. It will finally give information about the frequency of collocation opportunities for each specific swath segment.

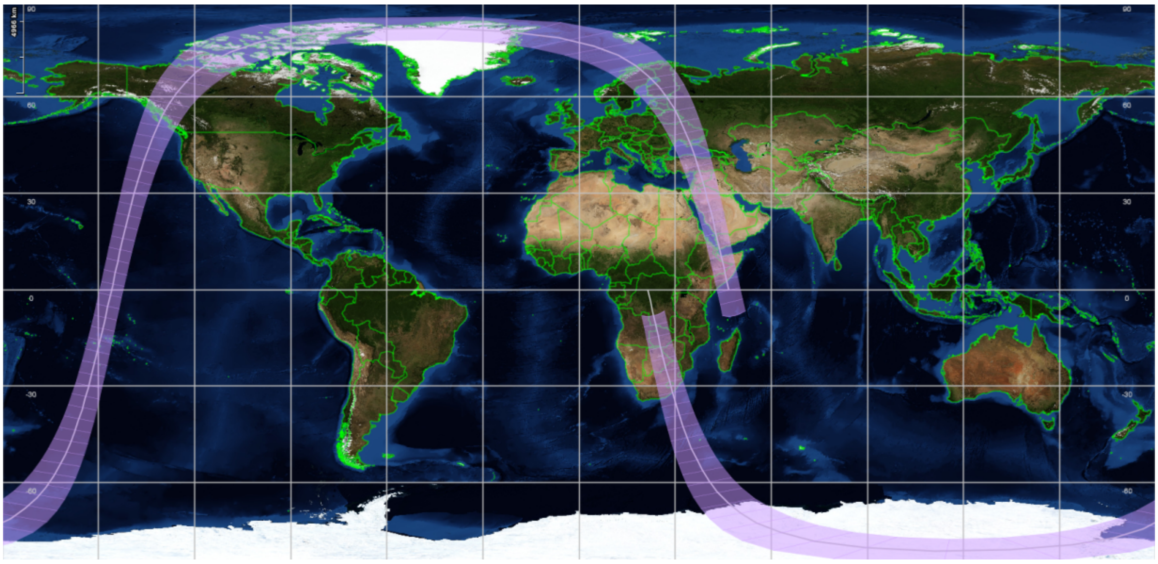


Figure 1 Ground swath for one orbit of master satellite, split into segments.

For each ground swath, the program evaluates the collocation opportunities. For it, it considers that the swath for the master satellite will be this one for the time t, and also for times t+RP1, t+ 2RC1, … , t+ CRC. Therefore, the program performs an iteration between k=0 and k=CRC/RC1, and uses the CFI visibility functions to find all the overlaps of the slave swath over the considered swath segment at the time t+k*RC1. The resulting delta overlaps between the two passes are calculated and only the ones that are smaller than the interest for the user are stored.
After the number of collocation opportunities is found for each swath segment along one orbit is found, this number is divided by the number of iterations performed, to find the frequency in which these collocation opportunities occur in this swath.
Final results are then written in a text file, a KML file and a SCF.

5.1.4 Output file format description

The executable program *InstrCollocationStats* generates various output files. Outputs are written in a text file, a KML file and a SCF. All of these modes contain the same information as the text file, but allow for different visualisation methods.

The text file has a HEADER containing relevant INPUT information.

Information on HEADER		
INPUT PARAMETERS	Definition	Value
Master satellite	Given identifier of master satellite in configuration file.	-
Master swath ID	Given identifier of swath ID of master satellite in configuration file.	-
Master repeat cycle	Repeat cycle of master cycle, extracted from the orbit file.	Days
Master cycle length	Cycle length of master cycle, extracted from the orbit file.	Master orbits
Slave satellite	Given identifier of slave satellite in configuration file.	-
Slave swath ID	Given identifier of swath ID of slave satellite in configuration file.	-
Slave repeat cycle	Repeat cycle of slave cycle,	Days

	extracted from the orbit file.	
Slave cycle length	Cycle length of slave cycle, extracted from the orbit file.	Slave orbits
Start for master orbit	Start of simulation for the master orbit. If entire lifespan is wanted, write 0.	Integer
Stop for master orbit	End of simulation for the master orbit. If entire lifespan is wanted, write the cycle length of master satellite.	Integer
Combined repeat cycle	Output. Least common multiple between both repeat cycles.	Days
Combined cycle length	Output. Cycle length for master satellite of combined repeat cycle.	Master orbits
Combined cycle length	Output. Cycle length for slave satellite of combined repeat cycle.	Slave orbits
First maximum time difference	Indicated in input file.	Minutes
Second maximum time difference	Indicated in input file.	Minutes
Third maximum time difference	Indicated in input file.	Minutes

The content contains information on overpasses.

Information on CONTENT		
INPUT PARAMETERS	**Definition**	**Value**
Index	Segment identifier	-
Center_latitude	Latitude of the center swath	Degrees
Center_longitude	Longitude of the center swath	Degrees
Intersections<First	Number of collocation opportunities per cycle with a time difference smaller than the first time difference of interest	Integer
Intersections<Second	Number of collocation opportunities per cycle with a time difference smaller than the second time difference of interest	Integer
Intersection<Third	Number of collocation opportunities per cycle with a time difference smaller than the third time difference of interest	Integer
Smallest difference	Smallest time difference with the first revisit opportunity	Minutes

The KML files show the same information in XML content so that it can be opened and visualised from Google Earth and so that it contains extra information at every segment that can be obtained by clicking on the desired swath.

The two file formats are therefore complementary.

5.1.5 Example

5.1.5.1 Running the executable

The executable program can be called in the following way:

- From Windows command prompt window

```
InstrCollocationStats.exe inputs\inputs_stats_s1_s1_example.txt
```

- From Mac OSX / Linux Terminal window

```
./InstrCollocationStats ./inputs/inputs_stats_s1_s1_example.txt
```

The executable program shows the following messages:

```
------------------
InstrCollocationStats v1.1.1
------------------

INPUTS:

MASTER Sat: SENTINEL1A
MASTER orbit file:
inputs/mission_configuration_files/SENTINEL1A/OSF/S1A_OPER_MPL_ORBSCT_20140507T150704_
99999999T999999_0020.EOF
MASTER swath: SAR1EW
MASTER swath file: inputs/mission_configuration_files/SENTINEL1A/SDF/SDF_SAR1EW.S1
SLAVE Sat: SENTINEL1B
SLAVE orbit file:
inputs/mission_configuration_files/SENTINEL1B/OSF/S1B_OPER_MPL_ORBSCT_20160425T224606_9
9999999T999999_0013.EOF
SLAVE swath: SAR1EW
SLAVE swath file: inputs/mission_configuration_files/SENTINEL1B/SDF/SDF_SAR1EW.S1
Time step: 150.000000
Minutes of interest: 8642.000000

Finished stage 196 of 196

Minutes spent 0.022582
```

5.1.5.2 Input File

The following text file was used as input configuration file:

```
#-------------------------------------------------------------------------
#SATELLITE 1
#-------------------------------------------------------------------------
#Satellite:
SENTINEL1A
#Orbit filename:
inputs/mission_configuration_files/SENTINEL1A/OSF/S1A_OPER_MPL_ORBSCT_20140507T150704_999999
99T999999_0020.EOF
#Swath ID:
SAR1EW
#Swath filename:
inputs/mission_configuration_files/SENTINEL1A/SDF/SDF_SAR1EW.S1
#-------------------------------------------------------------------------
#SATELLITE 2
#-------------------------------------------------------------------------
#Satellite:
SENTINEL1B
#Orbit filename;
inputs/mission_configuration_files/SENTINEL1B/OSF/S1B_OPER_MPL_ORBSCT_20160425T224606_999999
99T999999_0013.EOF
#Swath ID:
SAR1EW
#Swath filename:
```

```
inputs/mission_configuration_files/SENTINEL1B/SDF/SDF_SAR1EW.S1
#----------------------------------------------------------------------
#GENERAL
#----------------------------------------------------------------------
#Time step (seconds):
150
#Start orbit:
15495
#Stop orbit (including):
15499
#Maximum overlap difference (minutes):
8642.0
#Second overlap difference (minutes):
642.0
#Third overlap difference (minutes):
42.0
#KML FLAG
1
#SCF FLAG
0
```

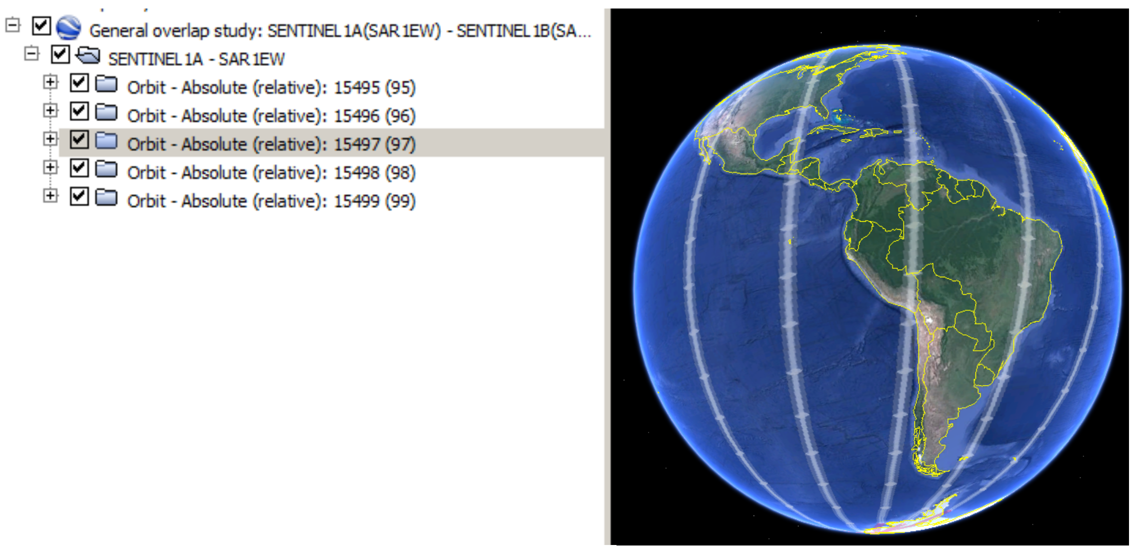
5.1.5.3 *Output File*

The output file SENTINEL1A(SAR1EW)_SENTINEL1B(SAR1EW)_orbit_15495_15499.*txt* is created. Excerpt of the example output file:

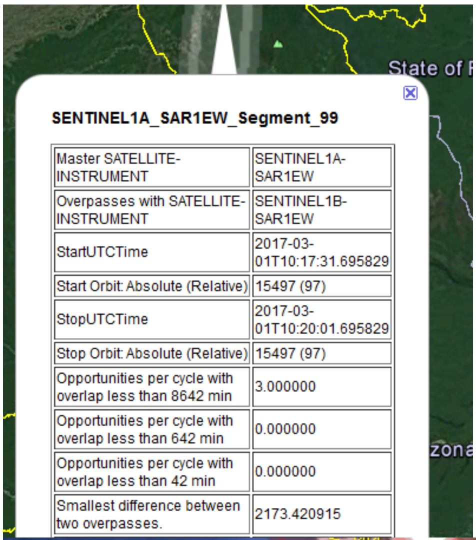
```
#Generated with executable tool InstrCollocationStats 1.1.1
#
#Master satellite: SENTINEL1A
#Master swath ID: SAR1EW
#Master repeat cycle: 12
#Master cycle length: 175
#
#Slave satellite: SENTINEL1B
#Slave swath ID: SAR1EW
#Slave repeat cycle: 12
#Slave cycle length: 175
#
#START for master orbit: 15495
#STOP for master orbit: 15499
#
#Combined repeat cycle (days): 12
#Combined cycle length (orbits master): 175.000000
#Combined cycle length (orbits slave): 175.000000
#
#Maximum time difference (mins): 8642.000000
#Second time difference (mins): 642.000000
#Third time difference (mins): 42.000000
#-------------------------------------------------------
#Index      Center_latitude (deg)        Center_longitude (deg)        Opportunities per
cycle <First        Opportunities per cycle <Second       Opportunities per cycle<Third
     Smallest difference
#--------------------------------------------------------
1    5.070763     88.628395     3.000000     0.000000     0.000000     2175.653928

2    14.146069    176.728705    3.000000     0.000000     0.000000     2162.984621

3    23.213083    174.789512    3.000000     0.000000     0.000000     705.590339

4    32.262176    172.729985    3.000000     0.000000     0.000000     708.792664

5    41.283435    170.429658    3.000000     0.000000     0.000000     3577.256924

6    50.264147    167.673906    5.000000     0.000000     0.000000     762.131515
```

[...]

If this information is visualized in Google Earth, information for different orbits appear in different folders.

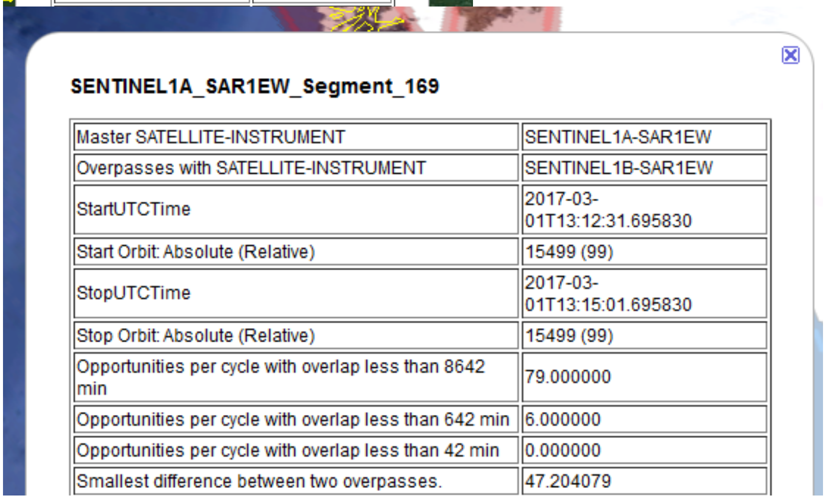


For every orbit, information for each specific swath can be obtained. The following images show first an example of a swath at the equator and second an example of a swath over Greenland. We know that there will always be one overlap with less than 8642 minutes time difference, given that there will always be an overlap with exactly 8460mis (6 days) difference. This tool tells us, however, that this swath at the equator will have more opportunities, and that the smallest time difference between overpasses is actually of 2173mins. Therefore, we can affirm that S1A and S1B will never have a collocation at the equator with a time difference less than 2170mins.
At the poles, clearly more orbits will overlap and the smallest time difference of overpasses is 47mins, with now 79 opportunities per cycle with less than 6 days difference.



SENTINEL1A_SAR1EW_Segment_99

Master SATELLITE-INSTRUMENT	SENTINEL1A-SAR1EW
Overpasses with SATELLITE-INSTRUMENT	SENTINEL1B-SAR1EW
StartUTCTime	2017-03-01T10:17:31.695829
Start Orbit: Absolute (Relative)	15497 (97)
StopUTCTime	2017-03-01T10:20:01.695829
Stop Orbit: Absolute (Relative)	15497 (97)
Opportunities per cycle with overlap less than 8642 min	3.000000
Opportunities per cycle with overlap less than 642 min	0.000000
Opportunities per cycle with overlap less than 42 min	0.000000
Smallest difference between two overpasses.	2173.420915



SENTINEL1A_SAR1EW_Segment_169

Master SATELLITE-INSTRUMENT	SENTINEL1A-SAR1EW
Overpasses with SATELLITE-INSTRUMENT	SENTINEL1B-SAR1EW
StartUTCTime	2017-03-01T13:12:31.695830
Start Orbit: Absolute (Relative)	15499 (99)
StopUTCTime	2017-03-01T13:15:01.695830
Stop Orbit: Absolute (Relative)	15499 (99)
Opportunities per cycle with overlap less than 8642 min	79.000000
Opportunities per cycle with overlap less than 642 min	6.000000
Opportunities per cycle with overlap less than 42 min	0.000000
Smallest difference between two overpasses.	47.204079

To see specific details about each of these opportunities, the program *InstrCollocationOpp* - detailed next - must be used.

5.1.6 Example 2

The example above, although it is useful for verification, is not very enlightening given the predictive behavior of S1A and S1B, given that they are in the same orbital plane. Therefore another example is now shown for satellites Sentinel3 (S3) and Sentinel2 (S2). Given that these two satellites have a similar Mean Local Solar Time, collocation opportunities with a short time difference will occur not only at the poles, but at all latitudes.

5.1.6.1 Running the executable

The executable program can be called in the following way:

- From Windows command prompt window

```
InstrCollocationStats.exe inputs\inputs_stats_s3_s2.txt
```

- From Mac OSX / Linux Terminal window

```
./InstrCollocationStats ./inputs/inputs_stats_s3_s2.txt
```

The executable program shows the following messages:

```
InstrCollocationStats v1.1.1
------------------

INPUTS:

MASTER Sat: SENTINEL3A
MASTER orbit file:
inputs/mission_configuration_files/SENTINEL3A/OSF/S3A_OPER_MPL_ORBSCT_20160216T191845_
99999999T999999_0004.EOF
MASTER swath: SLSTR_B
MASTER swath file: inputs/mission_configuration_files/SENTINEL3A/SDF/SDF_SLSTR_B.S3
SLAVE Sat: SENTINEL2A
SLAVE orbit file:
inputs/mission_configuration_files/SENTINEL2A/OSF/S2A_OPER_MPL_ORBSCT_20150625T073255_9
9999999T999999_0006.EOF
SLAVE swath: MSI
SLAVE swath file: inputs/mission_configuration_files/SENTINEL2A/SDF/SDF_MSI.S2
Time step: 150.000000
Minutes of interest: 642.000000

Finished stage 1049 of 1049

Minutes spent 0.199202
```

5.1.6.2 *Input File*

The following text file was used as input configuration file:

```
#-----------------------------------------------------------------------
#SATELLITE 1
#-----------------------------------------------------------------------
#Satellite:
SENTINEL3A
#Orbit filename:
inputs/mission_configuration_files/SENTINEL3A/OSF/S3A_OPER_MPL_ORBSCT_20160216T191845_999999
99T999999_0004.EOF
#Swath ID:
SLSTR_B
#Swath filename:
inputs/mission_configuration_files/SENTINEL3A/SDF/SDF_SLSTR_B.S3
#-----------------------------------------------------------------------
#SATELLITE 2
#-----------------------------------------------------------------------
#Satellite:
SENTINEL2A
#Orbit filename;
inputs/mission_configuration_files/SENTINEL2A/OSF/S2A_OPER_MPL_ORBSCT_20150625T073255_999999
99T999999_0006.EOF
#Swath ID:
MSI
#Swath filename:
inputs/mission_configuration_files/SENTINEL2A/SDF/SDF_MSI.S2
#-----------------------------------------------------------------------
#GENERAL
#-----------------------------------------------------------------------
#Time step (seconds):
150
#Start orbit:
15495
#Stop orbit (including):
15520
#Maximum overlap difference (minutes):
642.0
#Second overlap difference (minutes):
```

```
42.0
#Third overlap difference (minutes):
3.0
#KML FLAG
1
#SCF FLAG
0
```

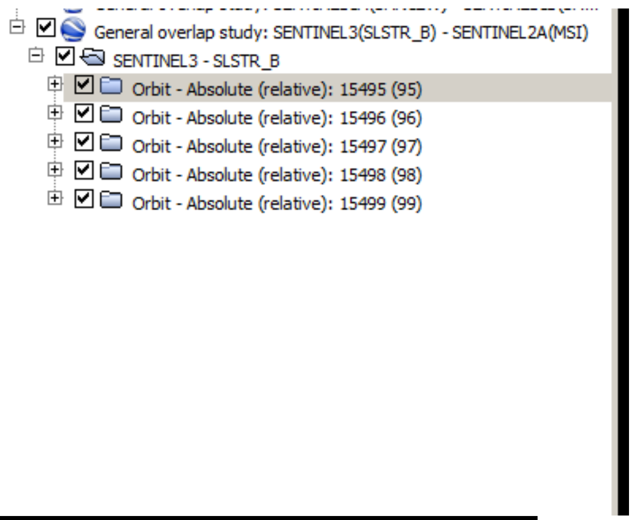
5.1.6.3 Output File

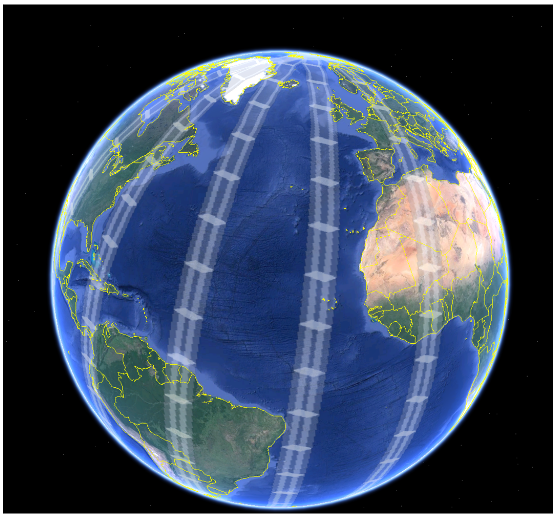
The output file SENTINEL1A(SAR1EW)_SENTINEL1B(SAR1EW)_orbit_15495_15495.*txt* is created. Excerpt of the example output file:

```
#Generated with executable tool InstrCollocationStats v1.1.1
#
#Master satellite: SENTINEL3
#Master swath ID: SLSTR_B
#Master repeat cycle: 27
#Master cycle length: 385
#
#Slave satellite: SENTINEL2A
#Slave swath ID: MSI
#Slave repeat cycle: 10
#Slave cycle length: 143
#
#START for master orbit: 15495
#STOP for master orbit: 15499
#
#Combined repeat cycle (days): 270
#Combined cycle length (orbits master): 3850.000000
#Combined cycle length (orbits slave): 3861.000000
#
#Maximum time difference (mins): 642.000000
#Second time difference (mins): 42.000000
#Third time difference (mins): 2.000000
#-------------------------------------------------------
#Index      Center_latitude (deg)         Center_longitude (deg)        Opportunities per
cycle <First        Opportunities per cycle <Second      Opportunities per cycle<Third
     Smallest difference
#--------------------------------------------------------
1    -3.724643      -175.255273    0.200000       0.200000       0.000000       31.745248
2    5.139623       -87.245657     0.200000       0.200000       0.000000       31.737282
3    13.986329      0.679255       0.200000       0.200000       0.000000       31.726599
4    22.804737      88.438460      0.300000       0.200000       0.000000       31.713652
5    31.582208      175.918265     0.600000       0.200000       0.000000       31.699028
6    40.300948      172.937508     0.900000       0.300000       0.000000       22.247454
```

[…]

If this information is visualized in Google Earth, information for different orbits appear in different folders.





For every orbit, information for each specific swath can be obtained. The following images show first an example of a swath at the equator and second an example of a swath next to Spain and Portugal. This tool tells us, that this swath at the equator will have 3 opportunities every 10 cycles of overpasses with less than 42mins difference. The least obtainable time difference at these latitude is of 12 minutes.

At the latitude of Portugal and Spain, there is one opportunity every 10 cycles of a collocation with a time difference less than 2 minutes (we know it has exactly 1.64mins time difference).

SENTINEL3_SLSTR_B_Segment_21

Master SATELLITE-INSTRUMENT	SENTINEL3-SLSTR_B
Overpasses with SATELLITE-INSTRUMENT	SENTINEL2A-MSI
StartUTCTime	2019-02-07T10:26:50.383106
Start Orbit: Absolute (Relative)	15495 (95)
StopUTCTime	2019-02-07T10:29:20.383106
Stop Orbit: Absolute (Relative)	15495 (95)
Opportunities per cycle with overlap less than 642 min	0.300000
Opportunities per cycle with overlap less than 42 min	0.300000
Opportunities per cycle with overlap less than 2 min	0.000000
Smallest difference between two overpasses.	12.008387

SENTINEL3_SLSTR_B_Segment_17

Master SATELLITE-INSTRUMENT	SENTINEL3-SLSTR_B
Overpasses with SATELLITE-INSTRUMENT	SENTINEL2A-MSI
StartUTCTime	2019-02-07T10:16:50.383106
Start Orbit: Absolute (Relative)	15495 (95)
StopUTCTime	2019-02-07T10:19:20.383106
Stop Orbit: Absolute (Relative)	15495 (95)
Opportunities per cycle with overlap less than 642 min	0.400000
Opportunities per cycle with overlap less than 42 min	0.400000
Opportunities per cycle with overlap less than 2 min	0.100000
Smallest difference between two overpasses.	1.644071

To see specific details about each of these opportunities, the program *InstrCollocationOpp* - detailed next - must be used.

5.2 Executable program *InstrCollocationOpp*

This program receives the information of the satellite orbit and instrument swath characteristics, and a maximum time difference the user is interested in analysing. It also receives a time/orbit window and zone of interest for the collocation opportunities to be analysed. Finally, it provides specific details of all collocation opportunities of interest within this window, within the zone of interest, and with a time difference less than the one specified.
It is worth mentioning that if the user is not interested in a particular zone, they can use a zone file containing the entire planet. Additionally, they can also use a zone file containing individual point targets of interest.

5.2.1 Command line input parameters description

The command line parameters of the executable routine are the following (provided in the order in which they have to be supplied):

INPUT PARAMETERS	Definition	Value
Input Configuration File	Filename (it may include the path to the file)	Given by the user

5.2.2 Configuration file input parameters

INPUT PARAMETERS	Definition	Value
SATELLITE 1		

Satellite	Satellite identifier	SENTINEL1A SENTINEL1B SENTINEL2A SENTINEL3A EARTHCARE METOP1 AEOLUS GENERIC
Orbit filename	Filename (it may include the path to the file)	
Swath ID	Swath ID of master satellite	
Swath filename	Filename (it may include the path to the file)	
SATELLITE 2		
Satellite	Satellite identifier	SENTINEL1A SENTINEL1B SENTINEL2A SENTINEL3A EARTHCARE METOP1 AEOLUS GENERIC
Orbit filename	Filename (it may include the path to the file)	
Swath ID	Swath ID of slave satellite	
Swath filename	Filename (it may include the path to the file)	
GENERAL		
Time step	Step for the simulation in seconds	
Mode	Mode for simulation window definition: TIME_RANGE: specify window by time. ORBIT_RANGE: specify window by orbit number of the master satellite	TIME_RANGE Or ORBIT_RANGE
Start	UTC / Integer	2017-03-08T14:54:01.857000 Or Orbit number
Stop	UTC / Integer	2017-03-08T14:54:01.857000 Or Orbit number
Zone filename	Zone filename (it may include the path to the file) Needs to be a .dbf	
Maximum overlap difference	Maximum time difference of interest in minutes	
KML FLAG	1- Write a KML file 0- Do not write a KML file	1 or 0
SCF FLAG	1- Write a SCF file 0- Do not write a SCF file	1 or 0

5.2.3 Process

The program first reads the input configuration file, and initialises all the information according to the orbit and swath files. After this, the simulation is started, and an iteration within the indicated time window and with the indicated time step is performed.
For each time step within the window, the program calculates the swath of the master satellite. For the given swath, it evaluates the collocation opportunities. For this, it analyses the time segments in which the slave satellite's swath intersects the master swath with a window centred in the present time of the master satellite, with a plus minus of the time difference of interest. All time segments are then written into the output files.

5.2.4 Output file format description

The executable program *InstrCollocationOpp* generates various output files. Outputs are written in two text files, and two KML files. For every type of file, one file is generated for the master satellite and one file is generated for the slave satellite information.

The text files have a HEADER containing relevant INPUT information. This information is the same in both text files.

Information on HEADER		
INPUT PARAMETERS	**Definition**	**Value**
Master satellite	Given identifier of master satellite in configuration file.	-
Master swath ID	Given identifier of swath ID of master satellite in configuration file.	-
Slave satellite	Given identifier of slave satellite in configuration file.	-
Slave swath ID	Given identifier of swath ID of slave satellite in configuration file.	-
Start for master orbit	Start of simulation for the master orbit.	UTC time
Stop for master orbit	End of simulation for the master orbit.	UTC time
Maximum time difference	Indicated in input file.	Minutes

The content contains information on overpasses. This information is different in the file containing master satellite information and in the satellite containing slave satellite information. The same number of segments will be shown in both files, and for the same segment identifier, the same time difference will be stated.

Information on CONTENT		
INPUT PARAMETERS	**Definition**	**Value**
Index	Segment identifier	-
Intersection_in_zone	Zone ID	-
START_ORBIT	Absolute orbit number of segment start	-
START_INTERVAL	Time of segment start	UTC
STOP_ORBIT	Absolute orbit number of segment Stop	-
STOP_INTERVAL	Time of segment stop	UTC

Delta_overpass - *(main output of interest)*	Time difference between the illumination at the centre swath between the two instruments.	Minutes
lat_1	Geodetic latitudes and geocentric longitudes of the four edges of the intersection swaths.	Degrees
lat_2		
lat_3		
lat_4		
lon_1		
lon_2		
lon_3		
lon_4		

The KML files show the same information in XML content so that it can be opened and visualised from Google Earth and so that it contains extra information at every segment that can be obtained by clicking on the desired swath.

The two file formats are therefore complementary.

5.2.5 Example

5.2.5.1 *Running the executable*

The executable program can be called in the following way:

- From Windows command prompt window

```
InstrCollocationOpp.exe inputs\inputs_opp_portugal.txt
```

- From Mac OSX / Linux Terminal window

```
./InstrCollocationOpp ./inputs/inputs_opp_portugal.txt
```

The executable program shows the following messages:

```
    InstrCollocationOpp v1.1.1
    ------------------

    INPUTS:

    MASTER Sat: SENTINEL3A
    MASTER orbit file:
inputs/mission_configuration_files/SENTINEL3A/OSF/S3A_OPER_MPL_ORBSCT_20160216T191845_
    99999999T999999_0004.EOF
    MASTER swath: SLSTR_B
    MASTER swath file: inputs/mission_configuration_files/SENTINEL3A/SDF/SDF_SLSTR_B.S3
    SLAVE Sat: SENTINEL2A
    SLAVE orbit file:
inputs/mission_configuration_files/SENTINEL2A/OSF/S2A_OPER_MPL_ORBSCT_20150625T073255_9
    9999999T999999_0006.EOF
    SLAVE swath: MSI
    SLAVE swath file: inputs/mission_configuration_files/SENTINEL2A/SDF/SDF_MSI.S2
    Time step: 60.000000
    Minutes of interest: 20.000000
    Zone file: inputs/zones/coast_portugal_spain.dbf


            -                    Repeat cycle = 27.000000
            -                    Cycle length = 385.000000
            -                    Repeat cycle = 10.000000
            -                    Cycle length = 143.000000

    NUM_ZONES=1
```

```
ZONE#1: coastline_portugal
   Segment 57 of 57

Minutes spent 0.008088
```

5.2.5.2 *Input File*

The following text file was used as input configuration file:

```
#-------------------------------------------------------------------------------------------
----------
#SATELLITE 1
#-------------------------------------------------------------------------------------------
----------
#Satellite:
SENTINEL3
#Orbit filename:
inputs/OSF/S3A_OPER_MPL_ORBSCT_20160216T191845_99999999T999999_0004.EOF
#Swath ID:
SLSTR_B
#Swath filename:
inputs/SDF/SENTINEL3/SDF_SLSTR_B.S3
#-------------------------------------------------------------------------------------------
----------
#SATELLITE 2
#-------------------------------------------------------------------------------------------
----------
#Satellite:
SENTINEL2A
#Orbit filename;
inputs/OSF/S2A_OPER_MPL_ORBSCT_20150623T033125_99999999T999999_0006.EOF
#Swath ID:
MSI
#Swath filename:
inputs/SDF/SENTINEL2/SDF_MSI.S2
#-------------------------------------------------------------------------------------------
----------
#GENERAL
#-------------------------------------------------------------------------------------------
----------
#Time step (seconds):
60
#Mode (TIME_RANGE or ORBIT_RANGE)
TIME_RANGE
#Start ASCII:
2016-02-28T12:54:01.857000
#Stop ASCII:
2016-04-15T14:54:01.857000
#Zone filename:
inputs/zones/coast_portugal_spain.dbf
#Maximum overlap difference (minutes):
20.0
#KML FLAG
1
#SCF FLAG
0
```

5.2.5.3 *Output File*

Two output text files and two KML files are created:

- SENTINEL3(SLSTR_B)_SENTINEL2A(MSI)__SENTINEL3_SLSTR_B__20160228T125402_20160415T145402.txt
- SENTINEL3(SLSTR_B)_SENTINEL2A(MSI)__SENTINEL2A_MSI__20160228T125402_20160415T145402.txt
- SENTINEL3(SLSTR_B)_SENTINEL2A(MSI)__SENTINEL3_SLSTR_B__20160228T125402_20160415T145402.KML

- SENTINEL3(SLSTR_B)_SENTINEL2A(MSI)__SENTINEL2A_MSI__20160228T125402_20160415T145402.KML

TEXT FILES :

Master satellite

```
#Generated with executable tool InstrCollocationOpp v1.1.1
#
#Master satellite: SENTINEL3A
#Master swath ID: SLSTR_B
#Slave satellite: SENTINEL2A
#Slave swath ID: MSI
#START for master orbit: 2016-02-28T12:54:01.857000
#STOP for master orbit: 2016-04-15T14:54:01.857000
#Maximum time difference (mins): 20.000000
#---------------------------------------------------
#FILE FOR: SENTINEL3 - SLSTR_B
#---------------------------------------------------
#Index      Intersection_in_zone    START_ORBIT    START_INTERVAL        STOP_ORBIT
STOP_INTERVAL       Delta_overpass (mins)        lat_1    lat_2    lat_3    lat_4    lon_1    lon_2
     lon_3    lon_4
#---------------------------------------------------
1    coastline_portugal      338     2016-03-11T11:16:32.629762     338     2016-03-
11T11:17:32.629762           12.563589       43.557661       45.415255       41.914689
40.100574     -5.229549      -9.695746       -10.978028      -6.726047
2    coastline_portugal      338     2016-03-11T11:17:32.629762     338     2016-03-
11T11:18:32.629762           12.571204       40.100574       41.914689       38.404473
36.627398     -6.726047      -10.978028      -12.153029      -8.084439
3    coastline_portugal      338     2016-03-11T11:18:32.629762     338     2016-03-
11T11:18:36.978275           12.578183       36.627398       38.404473       38.149751
36.375142     -8.084439      -12.153029      -12.234644      -8.178249
4    coastline_portugal      666     2016-04-03T11:20:13.009186     666     2016-04-
03T11:21:13.009186           18.744341       43.793909       45.654755       42.154933
40.338058     -6.056213      -10.538337      -11.828927      -7.563291
5    coastline_portugal      666     2016-04-03T11:21:13.009186     666     2016-04-
03T11:22:13.009186           18.752450       40.338058       42.154933       38.645313
36.865877     -7.563291      -11.828927      -13.010526      -8.930258
6    coastline_portugal      723     2016-04-07T11:16:32.718883     723     2016-04-
07T11:17:32.718883           2.688761        43.557661       45.415255       41.914689
40.100574     -5.229549      -9.695746       -10.978028      -6.726047
7    coastline_portugal      723     2016-04-07T11:17:32.718883     723     2016-04-
07T11:18:32.718883           2.631884        40.100574       41.914689       38.404473
36.627398     -6.726047      -10.978028      -12.153029      -8.084439
```

Slave satellite

```
#Generated with executable tool InstrCollocationOpp v1.1.1
#
#Master satellite: SENTINEL3A
#Master swath ID: SLSTR_B
#Slave satellite: SENTINEL2A
#Slave swath ID: MSI
#START for master orbit: 2016-02-28T12:54:01.857000
#STOP for master orbit: 2016-04-15T14:54:01.857000
#Maximum time difference (mins): 20.000000
#---------------------------------------------------
#FILE FOR: SENTINEL2A - MSI
#---------------------------------------------------
#Index      Intersection_in_zone    START_ORBIT    START_INTERVAL        STOP_ORBIT
STOP_INTERVAL       Delta_overpass (mins)        lat_1    lat_2    lat_3    lat_4    lon_1    lon_2
     lon_3    lon_4
#---------------------------------------------------
1    coastline_portugal      3752    2016-03-11T11:29:01.285917     3752    2016-03-
11T11:30:11.604247           12.563589       44.069340       44.734046       40.610003
39.970672     -4.542669      -8.058021       -9.380944       -6.082699
2    coastline_portugal      3752    2016-03-11T11:30:02.221519     3752    2016-03-
11T11:31:11.582458           12.571204       40.518592       41.160954       37.083766
36.461602     -5.886683      -9.211490       -10.420838      -7.276941
```

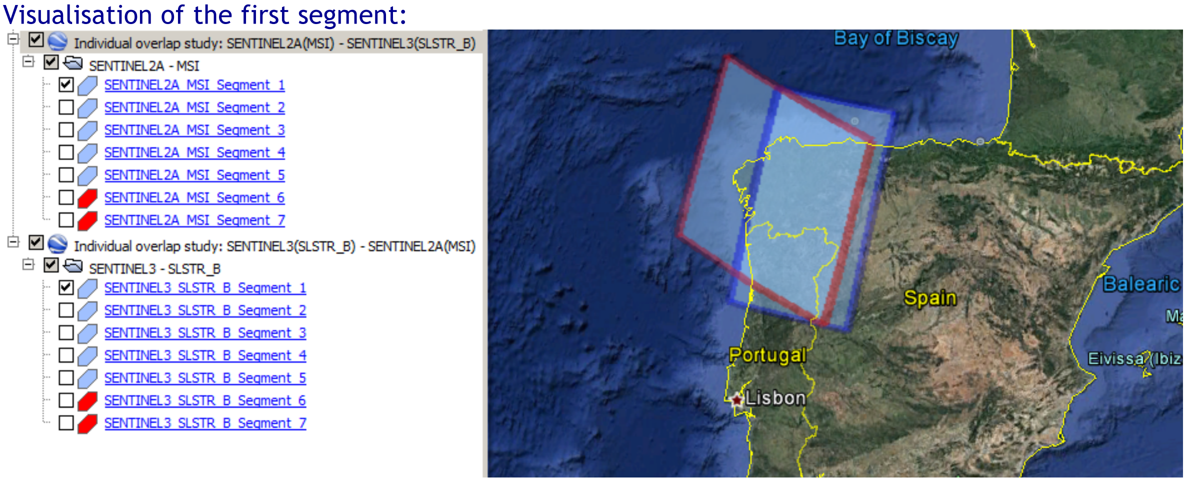
```
3    coastline_portugal    3752    2016-03-11T11:31:03.061306    3752    2016-03-
11T11:31:15.928699    12.578183    36.960787    37.585174    36.827968
36.206913    -7.113038    -10.277330    -10.493533    -7.359857
4    coastline_portugal    4081    2016-04-03T11:38:51.516866    4081    2016-04-
03T11:40:03.822418    18.744341    44.883466    45.554035    41.315757
40.672525    -6.731877    -10.295848    -11.680963    -8.348575
5    coastline_portugal    4081    2016-04-03T11:39:52.153652    4081    2016-04-
03T11:41:04.158695    18.752450    41.353419    42.000599    37.769930
37.144707    -8.100009    -11.466672    -12.741570    -9.569649
6    coastline_portugal    4138    2016-04-07T11:19:12.836747    4138    2016-04-
07T11:20:15.252327    2.688761    43.155998    43.814475    40.152161
39.515271    -2.384000    -5.847107    -7.002734    -3.726037
7    coastline_portugal    4138    2016-04-07T11:20:14.250879    4138    2016-04-
07T11:21:07.012939    2.631884    39.573793    40.210993    37.108660
36.486387    -3.705482    -6.984926    -7.896256    -4.751361
```

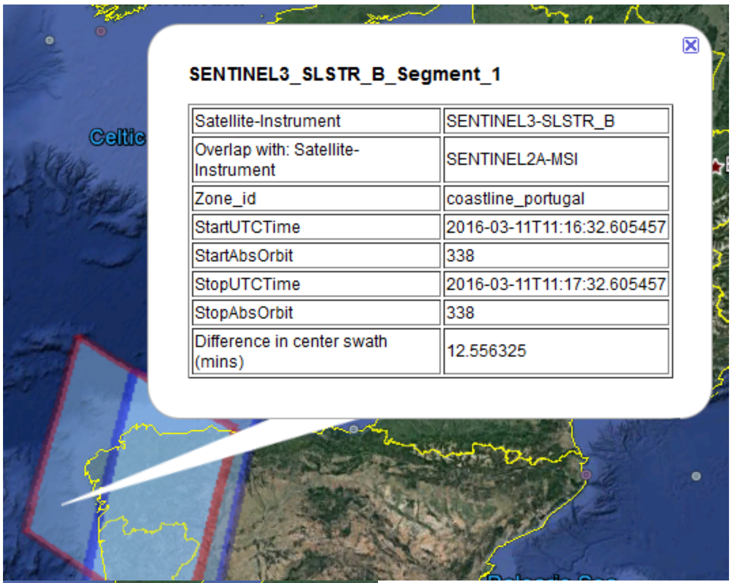
KML FILES:

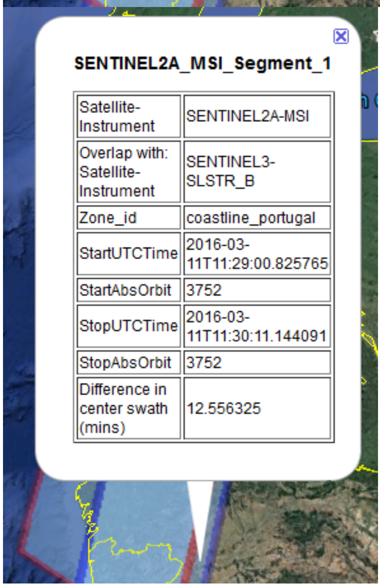
When opened from Google Earth, there is one folder with all the S3 swath segments and one folder with S2 swath segments. Every segment has an index. When only observing the same index in both folders, two overlapping swaths will be visualised.

The master satellite swath appears with a red outline, while the slave satellite outline appears with a blue outline. When these swath segments are clicked, the extra information available for both satellites is showed. The difference of time of the overpass is going to be the same in both information bubbles.

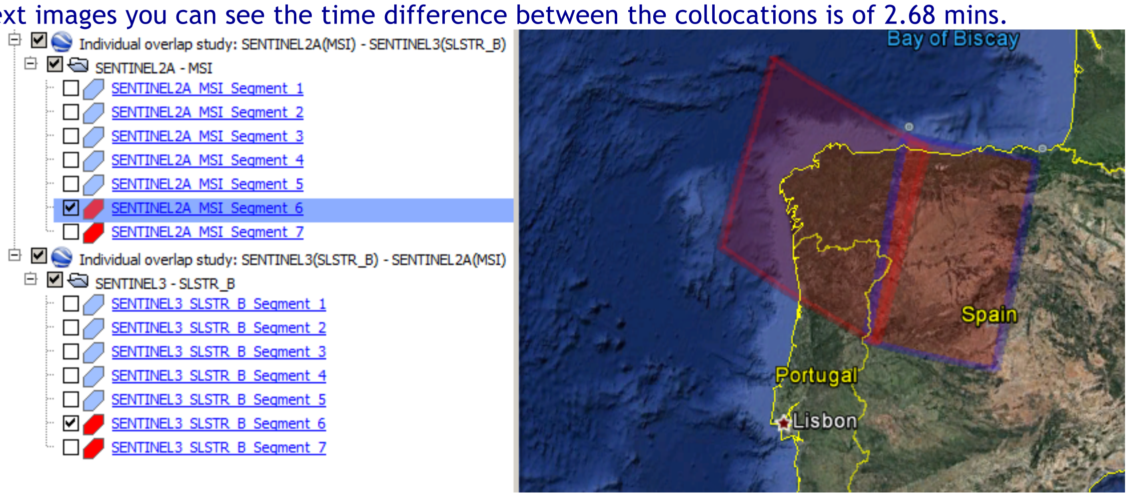
Visualisation of the first segment:

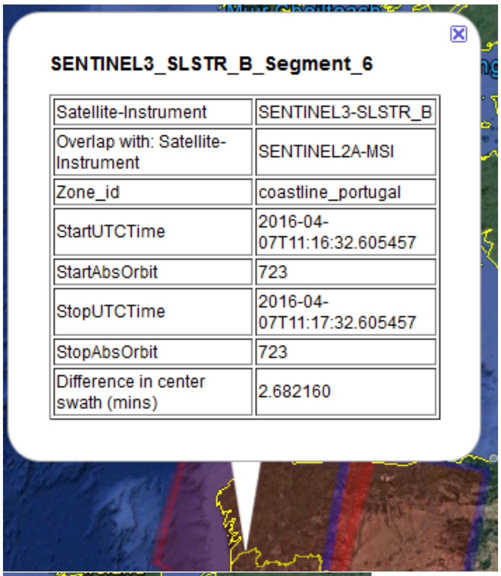






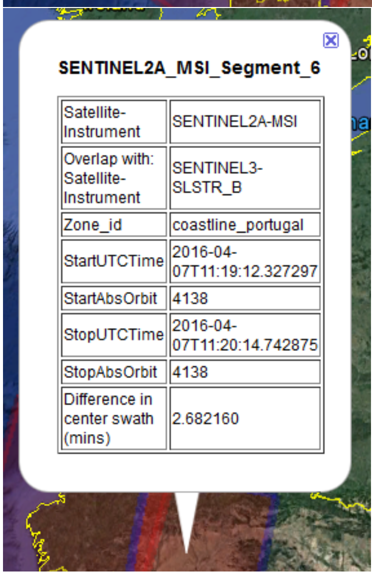
Visualisation of another segment – Segment fill is red when time difference is very small. In the next images you can see the time difference between the collocations is of 2.68 mins.





SENTINEL3_SLSTR_B_Segment_6

Satellite-Instrument	SENTINEL3-SLSTR_B
Overlap with: Satellite-Instrument	SENTINEL2A-MSI
Zone_id	coastline_portugal
StartUTCTime	2016-04-07T11:16:32.605457
StartAbsOrbit	723
StopUTCTime	2016-04-07T11:17:32.605457
StopAbsOrbit	723
Difference in center swath (mins)	2.682160



SENTINEL2A_MSI_Segment_6

Satellite-Instrument	SENTINEL2A-MSI
Overlap with: Satellite-Instrument	SENTINEL3-SLSTR_B
Zone_id	coastline_portugal
StartUTCTime	2016-04-07T11:19:12.327297
StartAbsOrbit	4138
StopUTCTime	2016-04-07T11:20:14.742875
StopAbsOrbit	4138
Difference in center swath (mins)	2.682160

Note that in the example 2 of the usage of InstrCollocationStats, results showed how in a region close to the studied one, at the same latitude, there was one opportunity of overlap with 2 minutes of time difference every 10 cycles of Sentinel3. This very little time difference could therefore be anticipated, and not expected again until 10 cycles of Sentinel 3 are fulfilled.

6. TECHNICAL DETAILS AND ASSUMPTIONS

6.1 Earth Observation CFI Software Version

The executable tools have been generated using EO CFI v4.12.

6.2 Repeat Cycle and Cycle Length

In the sun-synchronous orbits, the ground track repeats precisely after a constant integer number of orbits and a constant duration. The duration in days of that period is called the repeat cycle, whereas the corresponding number of orbits is called the cycle length.

6.3 Absolute Orbit Number

The absolute orbit number considers the orbits elapsed since the first ascending node crossing after launch.

6.4 Relative Orbit Number and Cycle Number

The relative orbit number is a count of orbits from 1 to the number of orbits contained in a repeat cycle. The relative orbit number 1 corresponds to the orbit whose ascending node crossing is closest to the Greenwich Meridian (eastwards). The relative orbit number is incremented in parallel to the absolute orbit number up to the cycle length, when it is reset and the cycle number is incremented by one.

A cycle is defined as a full completion of the repeat period. A cycle starts by definition on an ascending node crossing closest to the Greenwich Meridian.