DOCUMENT

# Impact of the Envisat Mission Extension on SAR data

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| **Prepared by** | **nuno miranda** |
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# 1 INTRODUCTION

Envisat has reached 8 years of operations in 2010, while its originally foreseen mission lifetime was 5 years. The excellent performance of the satellite, the wide user demand and the need to bridge the gap with the GMES Sentinel missions called for a 3-year mission extension until 2013, which was approved last year by ESA Member States.

The pre-requisite for such mission extension until 2013 is however to find a solution for operating Envisat with a minimum amount of hydrazine. The on-board hydrazine is indeed the main limiting factor for the satellite lifetime. 314 kg of hydrazine were on-board Envisat before its launch, i.e. the same amount as for the ERS satellites, though Envisat is about 4 times heavier than ERS. Such low hydrazine amount was meant to be sufficient for a 5-years nominal lifetime. Thanks to an excellent launch performance as well as a very careful consumption strategy during the last 8 years of operations, there is still about 25% of available hydrazine (i.e. 77 kg +/- 10%).

In 2007, ESA developed a technical solution for extending the Envisat mission beyond 2010, addressing the hydrazine issue. The following four criteria were used to elaborate such technical solution:

1. to keep the current nominal mission for as long as possible (i.e. until 2010),
2. to extend the mission well beyond 2010,
3. to ensure the continuity of the maximum number of Envisat applications beyond 2010,
4. to comply with the satellite disposal rules.

A new orbit control strategy allows fulfilling all the above criteria. It is based on lowering the orbit by 17.4 km as well as discontinuing the current orbit inclination control, which is the main source of hydrazine consumption. Such strategy leads to a new 30-day repeat cycle (431 orbits per cycle), instead of 35-day repeat cycle (501 orbits per cycle).

**The new orbit control strategy will be implemented starting on 22nd October 2010** and will allow a lifetime extension by about 3 years, i.e. until end 2013 – early 2014.

The new orbit configuration supports all current Envisat applications except SAR Interferometry (InSAR) applications which will be supported with some restrictions. These restrictions are due to the drift of the on-ground satellite track, in consequence of discontinuing the orbit inclination control. For this reason, a refinement will be implemented on the new orbit configuration to mitigate the negative impact on InSAR applications: the orbital node will be rotated to minimise the InSAR baseline drift at a pre-defined latitude of 38 degrees, instead of Equator. This will allow maintaining Differential SAR Interferometry (DInSAR) applications over a narrow geographical latitude range covering most of the major tectonic and volcanic areas.

Considering the rupture with the previous mission phase (E2) it has been decided to associate to the mission extension a new phase number: phase E3.

# 2 SCOPE

This document summarises the impact of the Envisat Mission extension orbital configuration on the ASAR instrument, data and applications.

# 3 REFERENCE DOCUMENTS

[R- 1] ASAR auxiliary data files: http://earth.eo.esa.int/services/auxiliary_data/asar/
[R- 2] Measurement Data Definition and Format Description for ASAR, PO-ID-DOR-SY-0032

# 4 PARAMETERS OF ENVISAT MISSION EXTENSION ORBIT

**Main orbital parameters of the extension orbit (Phase E3):**

Altitude: 782.4 Km (-17.4 km)
Semi-major axis: 7,142,047 m
Eccentricity: 0.001158
Repeat cycle: 30 days / 431 orbits
Delta nodal period: -0.087 s/year

The figure below summarizes the main characteristics of the Envisat Extension orbit (no inclination control, larger Mean Local Solar Time excursion, fixed altitude):

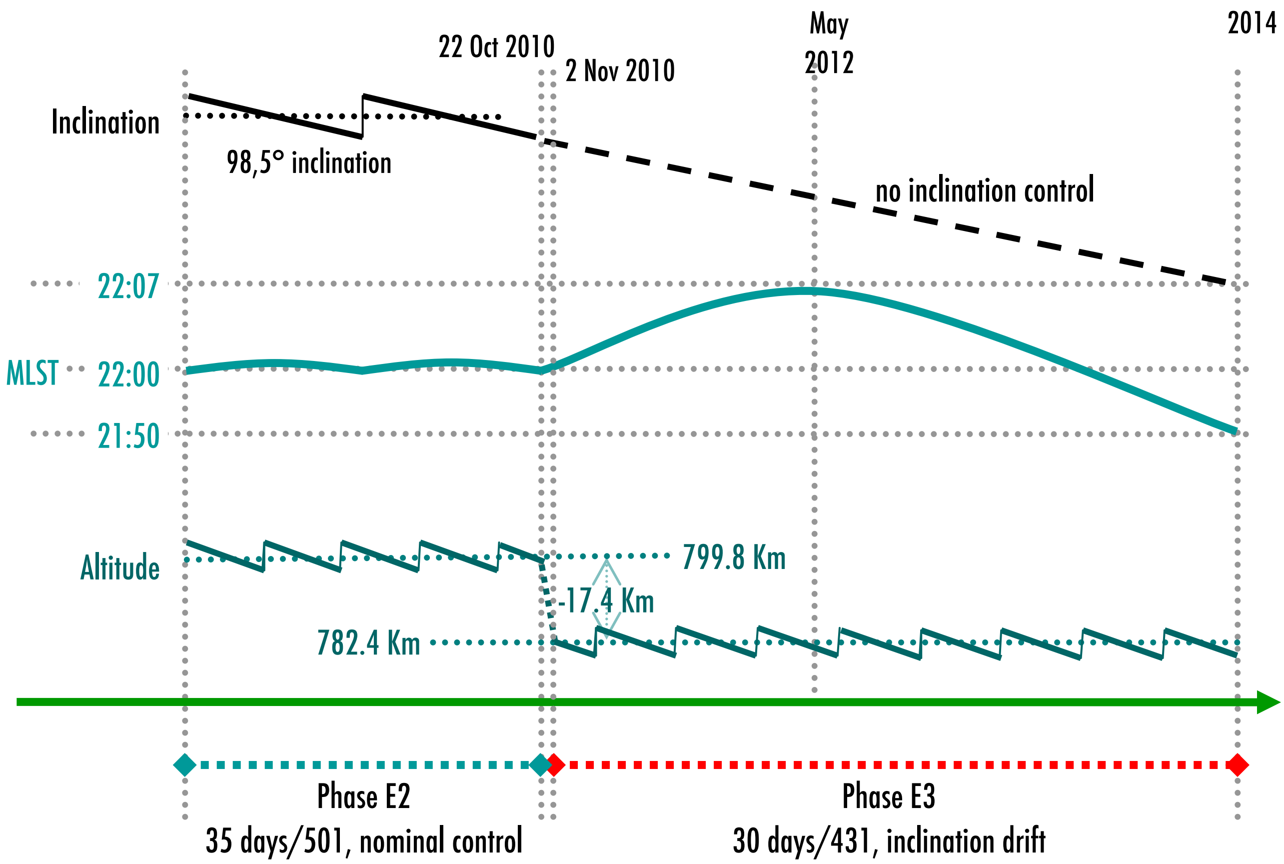


**Figure 1: Main characteristics of the Envisat Extension orbit (Phase E3)**

# 5 ASAR INSTRUMENT PARAMETERS UPDATE

The orbit lowering implies changes at instrument level for maintaining the instrument performance and product quality similar to Phase E2. The parameter optimisation has been done following several constraints:

- keeping the beam as per their Phase E2 definition such that no Elevation Antenna Pattern characterisation will be necessary after the orbit change
- respecting timing consistency (no nadir return in the Rx window)
- keeping performance (e.g. DTAR, NES0,...) as per the Phase E2 level
- keeping the duty cycle ratio as per Phase E2 level
- keeping the ratio between the burst length and the PRI constant (ScanSAR modes only)

Following these constraints a new set of instrument parameters is defined for Phase E3: PRF, Chirp duration, SWL, SWST tables and M values. M is the number of PRI in ScanSAR burst; it will change slightly by ±1 PRI.

The other instrument characteristics like the chirp bandwidth will remain untouched. The modified instrument characteristics are provided in the Annex (section 7) where:

- Table 2: ASAR PRF minimum and maximum values for phase E3
- Table 3: ASAR chirp duration in microseconds for Phase E3
- Table 4: ASAR Echo SWL duration in microseconds for Phase E3
- Table 5: ASAR minimum and maximum SWST codes for Phase E3

The ASAR processor providers are welcome to verify the impact of these changes in their software. For what concerns the ESA ASAR processor (PF-ASAR) the changes are relatively small as most of the parameters are read:

- directly from ISP annotations [R- 2] that will reflect these changes or
- from the ASAR auxiliary data files that will be updated soon [R- 1]

The changes in instrument parameters will lead to an update of the ASA_INS_AX file. It is not expected to change the external calibration auxiliary file (ASA_XCA_AX) containing the elevation antenna patterns as the radiating beam patterns remain unchanged.

The main change in PF-ASAR consists in being able to support two different sets of parameters for Phase E2 and Phase E3. No change in the processing algorithm was necessary.

Tables 1.a and 1.b provide the Phase E3 swath characteristics for Stripmap and ScanSAR.

| ASAR swath name | swath width [km] | near ground range [km] | swath overlap [km] | near slant range [km] | mid elevation angle | mid incidence angle |
|---|---|---|---|---|---|---|
| IS1 | 108.3 | 172.2 | 0 | 791.0 | 18.8 | 16.69 |
| IS2 | 102.6 | 231.1 | 49.4 | 807.7 | 22.8 | 20.25 |
| IS3 | 80.6 | 327.6 | 6.0 | 844.2 | 28.7 | 25.33 |
| IS4 | 86.2 | 401.9 | 6.3 | 879.5 | 33.6 | 29.60 |
| IS5 | 62.0 | 479.9 | 8.2 | 922.2 | 37.5 | 32.88 |
| IS6 | 68.5 | 537.4 | 4.4 | 957.1 | 40.8 | 35.70 |
| IS7 | 56.6 | 600.8 | 5.2 | 998.4 | 43.8 | 38.12 |

**Table 1.a: Phase E3 ASAR swath parameters characteristics for Stripmap.**
The values are provided on a point located at the ascending node (Equator).

| ASAR swath name | swath width [km] | near ground range [km] | swath overlap [km] | near slant range [km] | mid elevation angle | mid incidence angle |
|---|---|---|---|---|---|---|
| **SS1** | 136.0 | 198.5 | 0 | 797.9 | 21.9 | 19.45 |
| **SS2** | 79.4 | 327.9 | 6.6 | 844.4 | 28.6 | 25.31 |
| **SS3** | 90.0 | 399.9 | 7.4 | 878.4 | 33.6 | 29.60 |
| **SS4** | 62.5 | 479.6 | 10.3 | 922.0 | 37.5 | 32.88 |
| **SS5** | 72.3 | 535.5 | 6.6 | 955.9 | 40.8 | 35.70 |

**Table 1.b: Phase E3 ASAR swath parameters characteristics for ScanSAR.**
The values are provided on a point located at the ascending node (Equator).

# 6 IMPACT ON INSAR APPLICATIONS AND BASELINE DRIFT

The Envisat mission extension scenario relies on new orbit definition and on different orbit control strategy. The current altitude and inclination drift control is replaced by an altitude control only. The inclination drift will therefore not be compensated anymore as it was until October 2010. The consequence is that the inclination value will gradually diminish as illustrated in Figure 2.

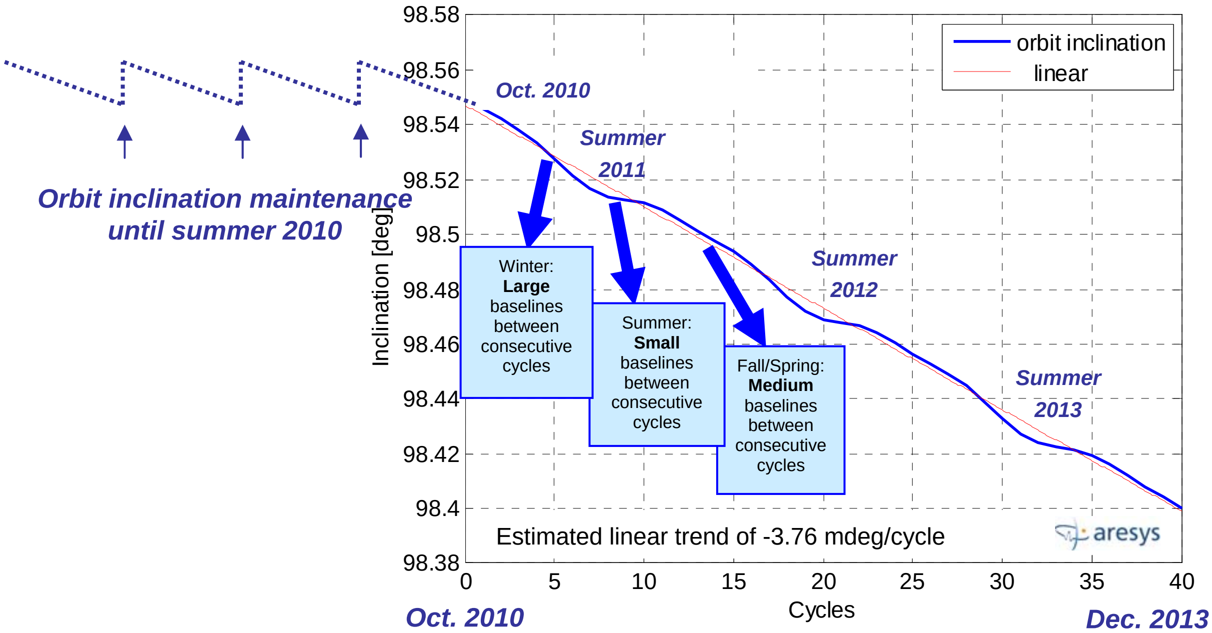


**Figure 2: Evolution of the orbit inclination during Phase E3**

The orbit inclination drift has a strong impact on InSAR applications as it directly contributes to increasing the values of the InSAR baselines. The (perpendicular) baseline is a critical aspect for SAR interferometry, as it determines the amount of spatial (geometrical) decorrelation in one side (range spectra overlap) and gives more strength to the undesired stereographic effect when dealing with Differential InSAR where the topographic contribution has to be kept at a minimum value.

The new orbit configuration has been further refined, in order to ensure that the InSAR baselines will be kept at a minimum value at a pre-defined latitude, and not at Equator. This pre-defined latitude is 38 deg North for descending passes and 38 deg South for ascending passes. This is illustrated in Figure 3 where the inclination is strongly exaggerated for illustration purposes.

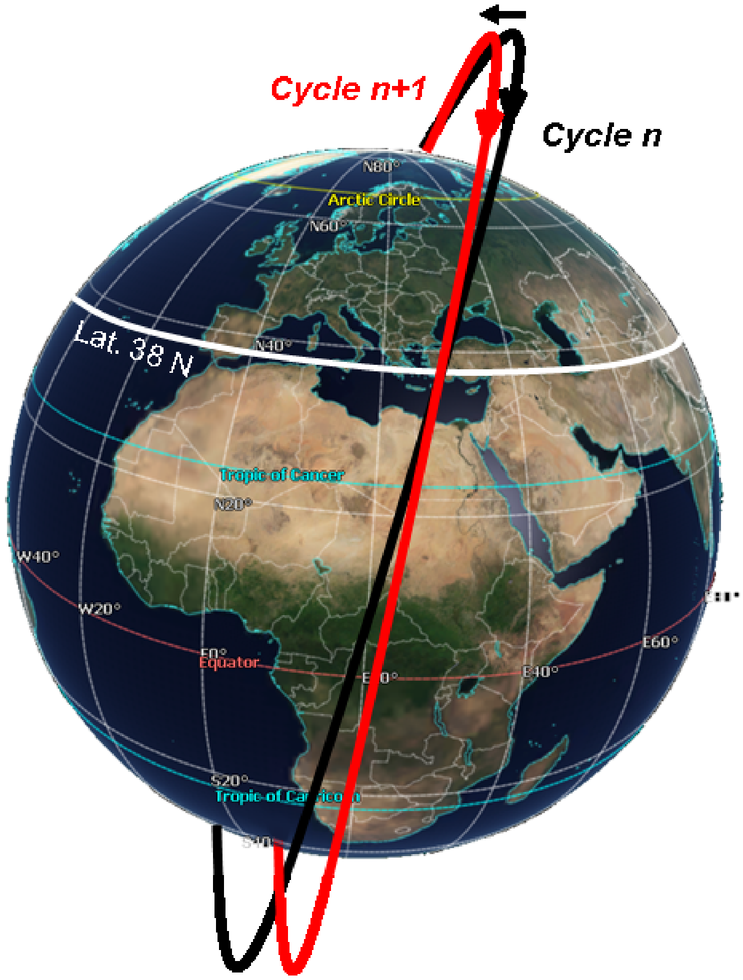


**Figure 3: Impact of the inclination drift for the same track of two successive cycles. The inclination drift induces a rotation of the orbital plane around 38° latitude (North for descending passes and South for ascending passes).**

The pre-defined latitude of 38 deg North corresponds to the largest number of geographical areas monitored in the past by InSAR (tectonics, volcanoes, subsidence), i.e. South Italy, Greece, Turkey, North Iran, Japan and North California.

The extent of the area where the baseline remains small strongly depends on the geometry of acquisition as the decorrelation effect is more important for near beams (e.g. IS1, IS2) than for far beams (e.g. IS6, IS7). InSAR theory introduces the concept of critical (perpendicular) baseline beyond which there is no signal correlation and therefore no interferometry. It is possible to estimate the extent of the latitude bands with multi-cycles baselines small enough to allow Differential InSAR. The latitude bands are defined as the latitude values for which the multi-cycles baselines remain smaller than the half critical baseline during the whole duration of the Phase E3 (40 cycles, i.e. 40 months). The DInSAR latitude bands are roughly:

± 1.3 deg for IS2

± 4.0 deg for IS6

The DInSAR latitude bands are illustrated in the figure below:

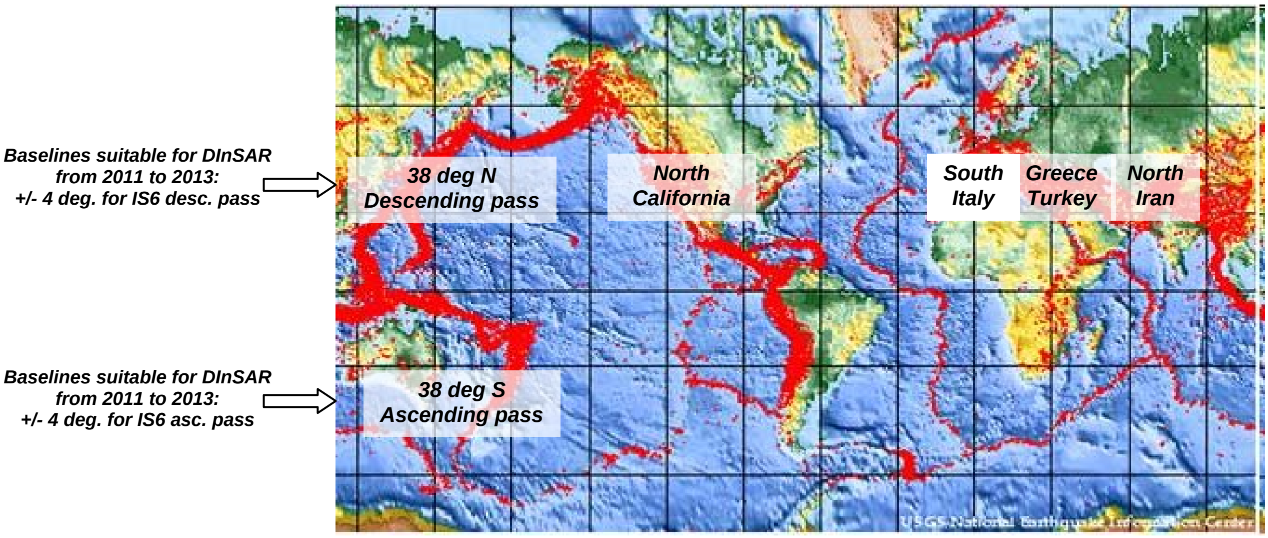


**Figure 4: DInSAR latitude bands for Phase E3 (2011 to 2013). Outside the DInSAR latitude bands, it is possible to find suitable interferometric pairs but essentially between consecutive cycles as the multi-cycle baseline will be too large for allowing InSAR.**

The evolution of the perpendicular baselines as a function of time and latitude is shown in Figure 5 below.

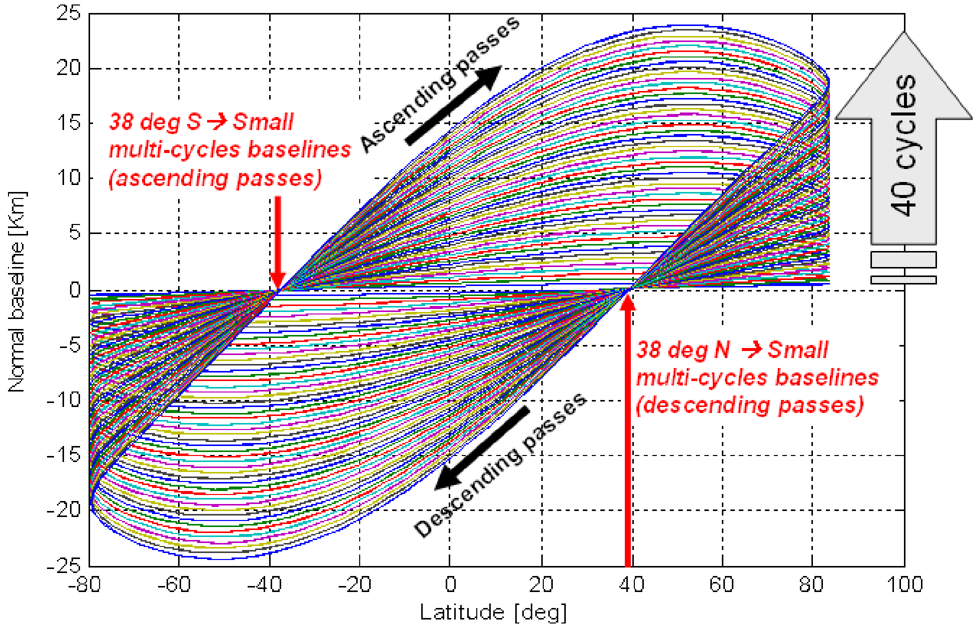


**Figure 5: Evolution of the perpendicular baseline values between a track of 1st cycle in Phase E3 and the same track for the successive 40 cycles, as a function of latitude and time (40 cycles, i.e. 40 months starting in November 2010).**

From the Figure 5, it can be deduced that perpendicular baselines between same tracks of 2 consecutive cycles have values compatible with InSAR. Figure 6 provides the estimated perpendicular baselines values as a function of time for different latitudes.

***Figure to be generated in next version of document***

**Figure 6: Evolution of the perpendicular baseline values between tracks of two consecutive cycles, as a function of latitude and time.**

# 7 ANNEX: PHASE E3 ASAR INSTRUMENT CHARACTERISTICS

| Phase E3 ASAR PRF (Hz) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| swath name | IM | | WV | | WS | | AP | | GM | |
| | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max |
| IS1 | 1746.153 | 1746.153 | 1746.153 | 1746.153 | - | - | 1746.15 | 1746.153 | - | - |
| IS2 | 1686.067 | 1686.067 | 1686.067 | 1686.067 | - | - | 1686.07 | 1686.067 | - | - |
| IS3/SS2 | 2123.804 | 2159.137 | 2123.804 | 2159.137 | 2125.684 | 2147.549 | 2123.8 | 2159.137 | 2124.74 | 2156.228 |
| IS4/SS3 | 1710.085 | 1732.294 | 1710.085 | 1732.294 | 1709.477 | 1726.068 | 1710.09 | 1732.294 | 1708.26 | 1722.971 |
| IS5/SS4 | 2102.417 | 2128.511 | 2102.417 | 2128.511 | 2104.260 | 2128.511 | 2102.42 | 2128.511 | 2102.417 | 2133.239 |
| IS6/SS5 | 1726.068 | 1744.884 | 1726.068 | 1744.884 | 1725.447 | 1744.250 | 1726.07 | 1744.884 | 1749.971 | 1749.971 |
| IS7 | 2084.167 | 2116.316 | 2084.167 | 2116.316 | - | - | 2084.17 | 2116.316 | - | - |
| SS1 | - | - | - | - | 1698.592 | 1710.695 | - | - | 1682.523 | 1705.227 |

**Table 2: ASAR PRF minimum and maximum values for Phase E3**

| Phase E3 ASAR Chirp Duration and Duty Cycle Ratio | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| swath name | IM | | WV | | WS | | AP | | GM | |
| | DC | Tx pulse Len [us] | DC | Tx pulse Len [us] | DC | Tx pulse Len [us] | DC | Tx pulse Len [us] | DC | Tx pulse Len [us] |
| IS1 | 0.045 | 25.7709376 | 0.045 | 25.7709376 | - | - | 0.045 | 25.7709376 | - | - |
| IS2 | 0.045 | 26.6893309 | 0.045 | 26.6893309 | - | - | 0.045 | 26.6893309 | - | - |
| IS3/SS2 | 0.045 | 21.1883959 | 0.045 | 21.1883959 | 0.036 | 76.524624 | 0.045 | 21.1883959 | 0.045 | 95.613435 |
| IS4/SS3 | 0.045 | 26.3144814 | 0.045 | 26.3144814 | 0.036 | 61.541172 | 0.045 | 26.3144814 | 0.045 | 76.8717 |
| IS5/SS4 | 0.045 | 21.4039365 | 0.045 | 21.4039365 | 0.036 | 75.75336 | 0.045 | 21.4039365 | 0.045 | 94.608765 |
| IS6/SS5 | 0.045 | 26.0708153 | 0.045 | 26.0708153 | 0.036 | 62.116092 | 0.045 | 26.0708153 | 0.045 | 78.748695 |
| IS7 | 0.045 | 21.59136 | 0.045 | 21.59136 | - | - | 0.045 | 21.59136 | - | - |
| SS1 | - | - | - | - | 0.036 | 61.149312 | - | - | 0.045 | 75.713535 |

**Table 3: ASAR chirp duration in microseconds for Phase E3**

| Phase E3 ASAR echo SWL [us] | | | | | |
|---|---|---|---|---|---|
| Swath | IM | WV | WS | AP | GM |
| IS1 | 226.680 | 226.680 | | 226.680 | |
| IS2 | 261.666 | 261.666 | | 261.666 | |
| IS3/SS2 | 256.46 | 256.460 | 252.659 | 256.460 | 252.659 |
| IS4/SS3 | 317.269 | 317.269 | 331.170 | 317.269 | 331.170 |
| IS5/SS4 | 251.306 | 251.306 | 253.597 | 251.306 | 253.597 |
| IS6/SS5 | 298.683 | 298.683 | 314.874 | 298.683 | 314.822 |
| IS7 | 261.301 | 261.301 | | 261.301 | |
| SS1 | | | 261.301 | | 329.191 |

**Table 4: ASAR Echo SWL duration in microseconds for Phase E3**

| Swath | IM | | WS | | GM | |
|---|---|---|---|---|---|---|
| | Min | Max | Min | Max | Min | Max |
| IS1 | 2232 | 5908 | | | | |
| IS2 | 832 | 4604 | | | | |
| IS3/SS2 | 1288 | 5248 | 1160 | 5116 | 1160 | 5116 |
| IS4/SS3 | 1664 | 5832 | 932 | 5100 | 932 | 5100 |
| IS5/SS4 | 700 | 5072 | 940 | 5308 | 940 | 5308 |
| IS6/SS5 | 1388 | 5964 | 1584 | 6164 | 1584 | 6164 |
| IS7 | 692 | 5484 | | | | |
| SS1 | | | 732 | 4480 | 732 | 4480 |

**Table 5: ASAR minimum and maximum SWST codes for Phase E3**