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Service Validation Protocol

C5

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V3

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CHANGE RECORD

Rev.	Date	Who	Changes
V1	?	?	Initial version
V2	12/04	S. le Mouelic, D. Raucoules (BGRM)	N/A (29 pages total)
V3	01/06	B. Kampes (DLR)	Added this change record; Restructured the document; Cleaned document from spurious formatting. Added cross-references; Included specific PSI weaknesses based on PSIC4 experiences; Included LSM and LSI products as level 2 and variants (not level 3); Included hybrid technologies as new product. Clarified difference between service/process/product validation and quality control; Included acronyms. Included applicable reference documents, removed bibliography. Included validation of new products/upgrades; Included DLR's role as external organ; Added UTM zone; Added validation flows for service/process/product validation. Added example validation report. Added availability section. Extended introduction, executive summary, conclusions; Removed original flow charts, sections on level2/3 validation.

Please note that C5 is currently under review by Terrafirma and should not be distributed. The scope and focus of C5 is to be discussed further by the Prime and DLR over the coming weeks.

17.02.06

APPLICABLE REFERENCE DOCUMENTS

- Terrafirma. *Core User Needs and User Standards*. Dossier U1, Version 2, July 2004.
- Terrafirma. *Service Level Agreement*. Dossier C7, Version 3, August 2004.
- Terrafirma. *Service Portfolio Specifications*. Dossier S5, Version 2, August 2004.
- Terrafirma. *Service Prospectus*. Dossier S3, Version 2, September 2004.

ACRONYMS

BRGM	Bureau de Recherches Geologiques et Minieres
CATInSAR	Compact Active Transponder InSAR
CE	Civil Engineering company
CRInSAR	Corner Reflector InSAR
CUG	Core User Group
DEM	Digital Elevation Model
DLR	Deutsches Zentrum für Luft- und Raumfahrt (German Aerospace Center)
EO	Earth Observation
ERS	European Remote Sensing Satellite
ETRS 89	European Terrestrial Reference System 1989
FTP	File Transfer Protocol
GIS	Geographical Information System
GPS	Global Positioning System
GRS80	Geodetic Reference System 1980
GS	Geological Survey
H1/2/3	Historic data product of level 1/2/3
InSAR	Interferometric SAR
INSPIRE	Infrastructure for Spatial Information in Europe
ISO	International Standard Organisation
LSI	Landslide Inventory (product)
LSM	Landslide Motion mapping (product)
M2	Monitoring data product (level 2)
NPA	Nigel Press Associates Ltd.
OSP	Operational Service Provider (also VAC)
PS	Persistent Scatterer
PSInSAR	Persistent Scatterer Interferometric SAR
QC	Quality Control
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
SLA	Service Level Agreement
UTM	Universal Transverse Mercator (projection)
VAC	(Earth Observation) Value Added Company (also OSP)

STRATEGY GROUP MEMBER ENDORSEMENT

I, the undersigned, confirm that I have read and endorse this dossier.

Strategy group member for policy

Name.....Signature.....

Strategy group member for science

Name.....Signature.....

Strategy group member for users

Name.....Signature.....

EXECUTIVE SUMMARY

This dossier describes the top-level definition of the approach for validating all constituents of the *Terrafirma* service portfolio. It establishes validation principles that are universally applicable to all products and services. Only level 1 products corresponding to raw InSAR measurements are clearly defined, whereas level 2 products including external data layers (causal) and level 3 products with global appraisal and modelling are foreseen. The validation principles for level 1 products and their production process are presented. In general, the validation is performed by the OSP and the End-User or owner of ancillary data. This dossier contains the definition, specification, and planned approach for monitoring compliance with user requirements for adherence to the (user driven) standards. This dossier defines and scopes the Service Validation report.

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1 INTRODUCTION

This document defines a series of procedures for validating *Terrafirma* products and services. These procedures ensure that the production procedures followed by all present and future OSPs are such that the quality of the delivered products conforms to the expectations of the end-users and that they adhere to the user-driven standards identified within the *Core User Needs and User Standards Dossier* (U1).

This Service Validation Protocol defines:

- Rules to ensure unbiased and independent validation (e.g., who can do the validation).
- Levels of validation.
- Top-level validation criteria, review process, and decision sequence.
- Requirements for validation reference data sources.
- The approach for validating new products.
- The approach for re-validating upgrades.
- The approach for long-term and short term validation.
- The approach for getting endorsement of validation from key external user-bodies.
- The approach for validating the service (as opposed to data products).
- Required validation documentation.
- Access, distribution and availability of validation documents.
- Maintenance of validation standards, reports and data sets for the *service portfolio*.
 - This Service Validation Protocol defines and scopes the Service Validation Report. As defined in the *Service Portfolio Specifications* (dossier S5), the *Terrafirma* service consists of:
 - The Terrafirma "shop window" (website)
 - The product ordering system
 - Product generation
 - Product delivery

Terrafirma offers two types of products, Historical and Monitoring. The former use SAR data already acquired, which reside in an archive, to make products that are as up-to-date as the latest acquisition. The monitoring product implies specific satellite tasking for future acquisitions. The historical product is available in three levels of sophistication, that build upon each other. The level 1 product is a 'raw' InSAR ground motion measurement. Level 2 involves some analysis by a geophysical expert when the result is integrated with other geospatial data to provide an initial interpretation of the cause of the motion observed. Level 3 products involve geophysical modelling to provide a risk assessment or some forecast as to future events.

Validation is key to provide assurances to the user communities. In *Terrafirma*, there are two main components to validation:

1. PROCESS validation: This is validation of the actual InSAR processing chain, to ensure that it produces consistent, reliable, and up-to-specification level 1 products. In addition, an overarching Quality Control standard will be implemented.
2. PRODUCT validation: This is validation that the measurements within a level 1 product have geological relevance.

The validation procedures detailed in this document foresee involvement of the interferometric producer (OSP) and the end-user or owner of ancillary data or specific expertise (for example CUG members). Furthermore, DLR acts as validation body, performing independent **process validation** of the processing chains to ensure that consistent, reliable, and up-to-specification products are generated by each OSP. This Service Validation Protocol does not define the implementation of the Quality Control (QC) of the individual processing chain of the OSP, but the procedures defined

in this dossier guarantee that the QC which is implemented at the OSP fulfil minimal requirements to ensure proper level 1 products.

1.1 Outline

The outline of this document is as follows. Sections 2, 3, and 4 describe the validation procedures for level 1, 2, and 3 products, respectively. The former section deals mainly with PROCESS validation, and the latter two with PRODUCT validation, because the higher level products involve analysis by a geo-physical expert of the level 1 "raw" measurements. The use of external ground truth data during processing and for validation is dealt with in section 5, whereas section 6 deals with the validation of new products and potential new Service Providers. Section 7 describes the availability of the validation reports. A summary and conclusions are given in section 8. The appendices contain tables that are to be included in the service validation report. An example service validation report is included in appendix 9.5.

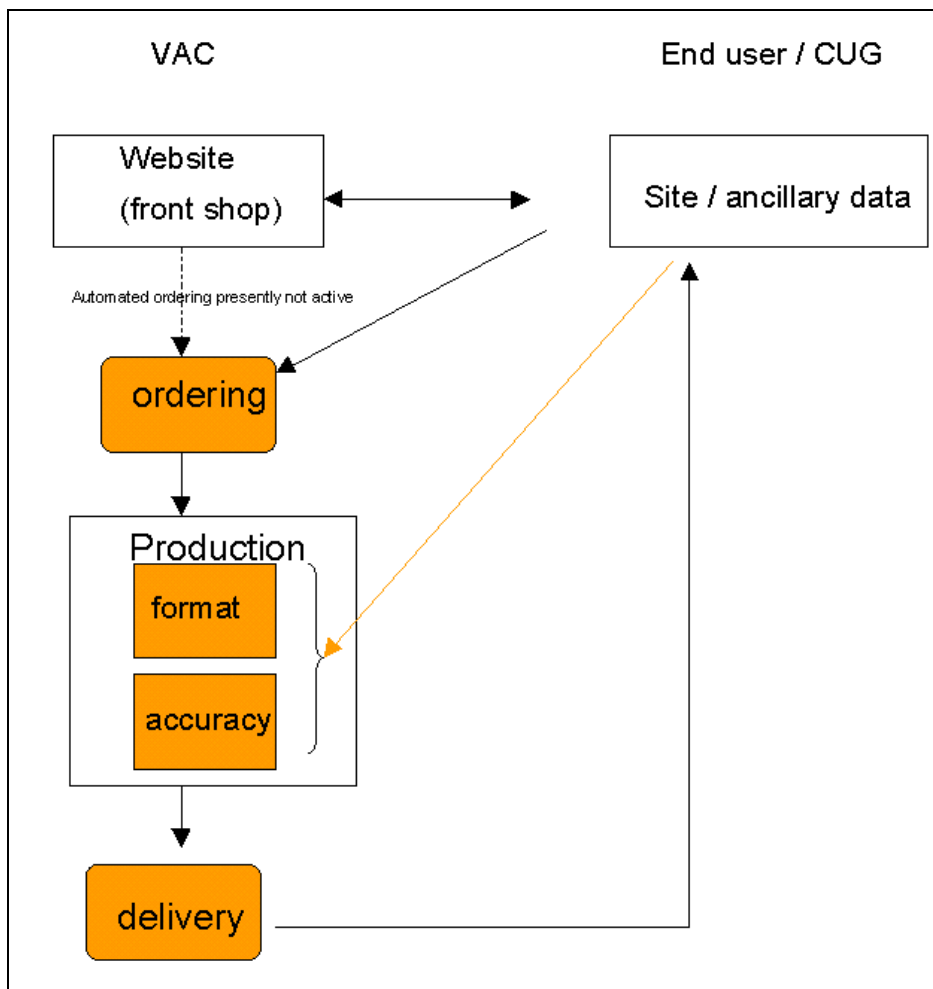


Figure 1: Elements of services for level 1 products that need to be validated (coloured blocks).

2 VALIDATION OF LEVEL 1 PRODUCTS

The level 1 products of the service portfolio are described in the dossier *Service Portfolio Specifications (S5)*. These products include the following types of InSAR measurements:

- Conventional differential interferogram.
- Stacked interferogram.
- Persistent Scatterer type analysis (PSInSAR).

Complete technical specifications are given for each of these products in the S5 dossier. In particular, it defines the standards used for the map projection type, the type of raster file used, and for the exchange of data in general. Figure 1 depicts a diagram of the services which need to be validated for H1 products. This validation protocol takes into account all aspects of the service portfolio constituents in three stages:

1. **Technical Conformity** of the delivered products to the agreed standards of the products and the services.
2. **PROCESS validation**. This ensures that procedures to detect and describe artefacts, e.g., from atmospheric origin, are in place at the OSP.
3. **PRODUCT validation**. This encompasses the relevance of the InSAR measurements, including an assessment of the accuracy/ precision of the InSAR measurements, both from a planimetric (horizontal) and a topometric (vertical) point of view.

These stages are described in sections 2.1, 2.2, and 2.3, respectively.

The conclusions of each step of the validation are to be included in the validation report. In addition, if the validation described in section **Error! Reference source not found.**, 2.1.3, and **Error! Reference source not found.** is negative, the delivered products need to be corrected by the OSP upon request of the End-User.

2.1 Technical conformity

2.1.1 Validation of the ordering procedure

- ▶ This step of the validation is carried out by the OSP and may be confirmed by the End-User after delivery.
- ▶ Service Validation Report: See appendix 9.1

Presently, the ordering system is based on emailing the user's national contact person. This system is evolving towards an automated system, see dossier S5. A validation protocol will be specified for this optimised system when it is defined. Nevertheless, some general elements can be presently validated. To proceed with the ordering of the products, the information provided by the end-user is:

- The geographic coordinates of the area of interest.
- The time period of interest.

A list of the proposed SAR images and preview amplitude image will be provided by the OSP to the End-User, in order to validate the agreement between the acquired data and the interest of the user.

2.1.2 Validation of the delivery

- ▶ This step of the validation is carried out by the OSP and may be confirmed by the End-User after delivery.
- ▶ Service Validation Report: See appendix 9.1 and appendix 9.2 (conventional differential InSAR), 9.3 (stacked InSAR), or 9.4 (PSInSAR).

The level 1 products are delivered by mailed CD-ROM or by FTP (see dossier S3 *service prospectus*). The following elements are to be checked by the end-user when receiving the product:

- Agreement between the ordered geographic limits and covered time period and the delivered product.

- Agreement between the ordered and the delivered product type and completeness of the delivered product (e.g., whether the processing report contains the minimum specifications).
- Delivery time. The ordering, production, and delivery process is expected to be done in less than (see *Terrafirma* Service Level Agreement):
 - Image InSAR: within 6 weeks.
 - PSInSAR: production after receipt of data 6 weeks; delivery 1 day via the internet, 1 week via mailed CD-ROM.

2.1.3 Conformity with the product standards

► This step of the validation is carried out by the OSP and may be confirmed by the End-User after delivery.

► Service Validation Report: See appendix 9.2 (conventional differential InSAR), 9.3 (stacked InSAR), or 9.4 (PSInSAR).

This step is aimed at verifying the conformity of the products with the agreed standards, such as file format, projection system, etc. A current European Commission initiative, INSPIRE, “aims at making available relevant, harmonised and quality geographic information to support formulation, implementation, monitoring and evaluation of Community policies with a territorial dimension or impact.” This work is heavily involved in standardising data across Europe. Its recommendations on data formats are relevant to the Terrafirma products and were taken into account in the definition of the data formats.

The defined standards, described in dossier S5, include in particular the use of the UTM projection system (Datum ETRS 89, Ellipsoid GRS80), with raster products delivered in georeferenced GeoTIFF format. Validation is performed using standardised tables which contain a checklist. This checklist is filled out by the OSP and the End-User to confirm that the delivered product is conforming to the standard.

2.2 Process validation

2.2.1 Conventional InSAR and stacked InSAR production

► No process validation is planned for conventional InSAR and stacked InSAR processing chains, because these are well established processing technologies with a low sensitivity for undetected errors in the processing. The OSP are to make sure the quality of the output product does not contain errors due to the processing algorithms.

► Service Validation report: N/A.

2.2.2 PSInSAR production chain

► *Subject to funding approval*, This step of the validation is carried out by DLR in collaboration with the OSP.

Process validation of the PSInSAR processing chains at the OSP is performed by DLR using its own PSInSAR processing chain and rigorous PSInSAR process verification procedures. This enables the validation of potential new OSPs, see also section 6.1. The usage of the DLR processing system serves as a possibility to determine a minimum quality standard by which all OSPs must abide. The procedures during PSInSAR processing are particularly important in the sense that deformation signal may be mis-interpreted as atmospheric signal, and that the height of the PS points may be difficult to estimate, depending on the PSInSAR algorithm used. The process validation is performed by DLR and consists of the following steps:

1. Audit: Experience of the scientific and software system engineer, operators and available resources in computing power, e.g., hard and software, are assessed based on interviews and/or written documentation provided by the OSP. This can include a list of key personnel and their curriculum vitae, publications in peer reviewed journals, internal software documentation internal, and descriptions of previous projects.
2. Quality Control (QC) documents of the OSP: Each OSP has implemented its own QC procedures. Based on this document and a comparison with an overarching QC standard, the PSInSAR processing chain is assessed. For example, this can include a requirement that critical steps during the processing are cross-checked by another operator (or another acceptable procedure to guarantee that, for example, the coregistration of all interferograms is of the best possible quality), and the requirement that processing results are reproducible by another operator.
3. Algorithmic assessment: Based on a 3-5 page description of the PSInSAR algorithm provided by the OSP, DLR will assess the procedure to handle typical problems with PSInSAR processing. This includes for example the robustness of the coregistration algorithm, the way platform position error are dealt with, the algorithm to estimate atmospheric signal, the way points are selected, the algorithm to estimate height and displacement, the procedure to exclude certain images during the processing, etc.
4. Cross-processing: The PSIC4 data set is used as standard data set to compare the processing results and delivered output. The OSP will process this area similar to the way as was done for the PSIC4 study, and deliver a historic level 1 product to DLR, including a service validation report. In first instance, DLR acts as the user and provides the area of interest, the expected displacement rates, patterns and location, ground control points and a stable reference point, orthophotos, etc. DLR will check the conformity of the product to the standards and compare the estimated displacement and geo-referencing by means of cross-processing using the DLR PSInSAR estimation algorithms. If requested by DLR, the OSP will provide additional components required for the validation, such as actual interferograms or all phase components of a PS point (original phase, topographic phase, displacement phase, atmospheric phase, orbit phase, residual phase), which can be tested in more detail to validate the algorithm. In special cases, another area (not the PSIC4 test area) can be processed by DLR and by the OSP, for example to confirm the presence or absence of a (non-linear) deformation phenomenon, or to validate new algorithms that are dedicated to new displacement patterns.

All four steps need to be validated positively. If a step is validated negatively, the remaining steps need not to be validated. The current OSP participated in the PSIC4 study and process validation was therefore performed for these OSPs. A diagram of the steps is provided in Table 3.

The process validation report contains sections for each of these validation steps, which include argumentation for the validation decision. The report also includes an executive summary that contains the outcome of the validation and the key argumentation. This summary is send to the Administrative Prime. The full report is confidential between DLR and the OSP that is validated. If the validation is negative, the OSP is allowed to make improvements and be validated again.

2.3 Product validation

- ▶ This step of the validation is carried out by the End-User or CUG members which provide the ground elements and the expertise on the deformation needed for validation.
- ▶ As noted in the following sections, the service validation report contains a description of ground truth data used during the processing and validation, and an assessment of the quality of the product when compared with these data.

The availability of ground data is an important issue on most test sites. Therefore, the validation procedure is not only based on geodetic data, but also on, e.g., cartographic material. The provision of ground data, and therefore this validation step, should be conditioned by an agreement on the properties and rights on the ancillary data used for processing and validation. Such agreements will be discussed further in the project, see also section 5.

2.3.1 Conventional InSAR and stacked InSAR production

- ▶ This step of the validation is carried out by the OSP.
- ▶ Service Validation report: See appendix 9.1.

2.3.1.1 Product artefacts of conventional InSAR and stacked InSAR

In the cases of conventional InSAR or stacked InSAR, some common effects could be misidentified as deformation signal. If the provided products contain effects that could affect the interpretation in terms of deformation, these effects have to be mentioned in the report when identified. This relates in particular to:

- Uncompensated topography: Due to local inaccuracies of the Digital Elevation Model used, uncompensated topography appears as a fringe pattern, the magnitude of which is proportional to the perpendicular baseline. Such artefact may be identified by comparing several interferograms.
- Atmospheric artefacts: In many cases, atmospheric effects can be misinterpreted as deformation signatures. As they do not repeat identically from one date to another, the comparison of several interferograms allows the identification of the phenomena.
- Platform position errors: If a phase trend is corrected using a baseline refinement or other method not using ground control points, this implies that possible displacement signal which has a trend is also removed. Use of such a correction method and the consequences for the reported deformation should be mentioned in the validation report.
- Unwrapping errors: Should be masked out where detected if unwrapped measurements are delivered.

2.3.1.2 Product accuracy assessment for conventional InSAR and stacked InSAR

- Planimetric (horizontal) accuracy: External data, such as an ortho-rectified aerial photo or cartographic data layers, or material available via the internet should be used to check the planimetric accuracy. A geo-referenced amplitude image should globally fit with these external data.
- Topometric (height) accuracy: If the height of the product is estimated, a measure should be provided how accurately this is done. This is important, because the accuracy of the geo-referencing is likely related to the accuracy of the height estimation.
- Displacement accuracy: Assessments of the maxima of deformation from InSAR must be compared with ground data assessments of the deformation for the period covered by the interferogram. The RMSE of the difference between ground-truth data and the InSAR measurements is included in the service validation report. An example of an assessment of the accuracy of the estimated accuracy is given in Figure 2.

In many cases, quantitative, geodetic, information could be unavailable, but the user can generally provide more qualitative information such as the spatial limits of subsidence bowls, approximate assessment of the maximum of deformation, location of damage caused by the deformation, etc. In those cases, the level of agreement between this a priori knowledge of the ground deformation and its mechanism and the radar measurement is to be described in the service validation report. Moreover, comments on the expectations of the agreement should be provided (regarding occurrence of vertical and horizontal motion, location and accuracy of the ground truth-data, etc.). As this kind of validation needs expertise both in radar interferometry and on the deformation

mechanism, it has to be carried out by the End-User in collaboration with the OSP. Such information is also used to complement the point validation when geodetic data are available.

- ▶ The service validation report must include a description of the known deformation phenomena (or reference to it) and a conclusion about the agreement with the measurements. A discussion should be included if the difference between measurements and ground-truth exceeds the expectations. Such a discussion could include statements on the difference in observation period by the radar measurements and the ground-truth data, the difference in observed parameters (e.g., radial vs. horizontal or vertical; compaction of the ground vs. stable buildings, etc.), etc.
- ▶ If ground-truth data have been available and used to correct the planimetry, topometry, or estimated displacement, usage is noted in the service validation report and described in the processing summary.

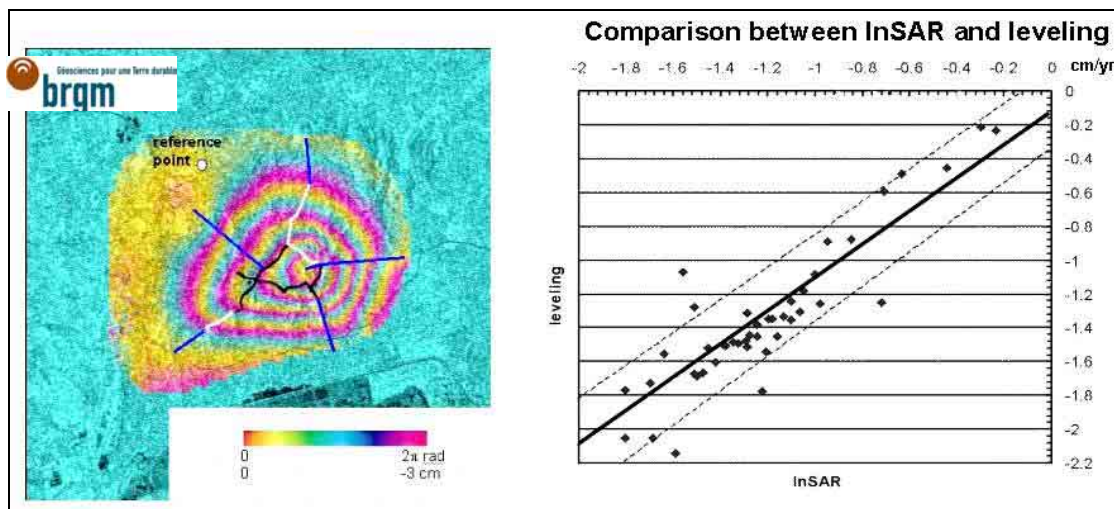


Figure 2 : Example of product validation of a classical InSAR stacked interferogram product by comparison with levelling data.

2.3.2 PSInSAR product validation

The displacement information provided by InSAR is the core of *Terrafirma*. Therefore, optimal product validation is a direct comparison with independent ground based methods such as levelling or GPS when available, which are the most widely used methods nowadays. Moreover, levelling and GPS have an official recognition in private companies and national, or legal, authorities that InSAR does not have, yet. The quantitative agreement between InSAR derived measurements and levelling or GPS measurements, at least on a part of a studied area, reinforces the reliability of the conclusions drawn for the whole area.

However, a direct comparison between ground-truth data and PsInSAR measurements is not always possible, and often complicated by the following factors:

- Lack of ground-truth data: In many cases, quantitative, geodetic, information could be unavailable, particularly in the area of interest. However, the user can generally provide qualitative information such as the spatial limits of subsidence bowls, an approximate assessment of the maximum of the deformation, the location of damage caused by the deformation, etc. In such cases, the level of agreement between this a priori knowledge of the ground deformation and its mechanism and the radar measurement is to be described in the service validation report. Moreover, comments on the expectations of the agreement should be provided (regarding occurrence of vertical and horizontal motion, location and accuracy of the ground truth-data, etc.). As this kind of validation needs expertise both in radar interferometry and on the deformation mechanism, it has to be carried out by the

End-User in collaboration with the OSP. Such information is also used to complement the point validation when geodetic data are available.

- Spatial sampling of the ground-truth data: If ground data is available, the density is likely much smaller than that of the PSInSAR product. The location of ground-truth data is often along profiles (roads) or at easily accessible places. The PS points are likely also present near such locations, but never at the exact same point. In many cases, the ground-truth data may not be located in the areas of maximum displacement. The distance of the ground-truth data to the PS point should be taken into account in the Service Validation Report.
- Temporal sampling of the ground-truth data: Ground-truth data is often acquired campaign-style (particularly levelling). Comparison with PSInSAR results is hampered by lower temporal sampling and non-overlap of the time intervals. A comparison of the displacement rate should take into account the difference in time intervals, and the precision of the rate computed using the ground-truth data.
- Precision of the ground-truth data: In many case the PSInSAR measurements may be more precise than available ground-truth data. The relevance of the ground-truth data is to be assessed by the End-User.
- Observed variates: PSInSAR measurements are sensitive to line-of-sight displacements of the radar target, possibly via multi-path reflections. The ground-truth data may be related to a different displacement. This relates to the influence of horizontal and vertical movement on the observables, the difference in compaction and subsidence (e.g., bore holes), the difference between displacement of a building and the surface, etc.

These factors complicate the validation of the PSInSAR results. The following sections propose a validation plan to reduce the impact of these factors.

2.3.2.1 PSInSAR product artefacts and common problems

PSInSAR products may suffer from errors due to the complex processing algorithms. The following list identifies the main errors and error sources for PSInSAR products. Assumed is a standard linear displacement model for the processing, and usage of a single-master data stack with more than 20 images. Other processing algorithms are likely to be affected by similar errors sources.

- Bias in the displacement rates: This relates to a single offset of all estimated displacement rates. Such an offset can be caused by instability of the reference point, to which all other points are measured.
- Bias in the estimated heights: This relates to a single offset in all estimated heights at all points. Such an offset can be caused by the assumption that the reference point is located on the reference body (DEM or ellipsoid), while it actually is not. The difference between the actual of ref.pnt, timing inaccuracy in rg, az.
- Bias in the georeferenced positions: This bias relates to a single offset in azimuth and a single offset in range direction, which are mapped to offsets in Northing (mainly azimuth) and Easting (mainly range). The offset in range direction can be caused by an error in the estimated height, and by a timing error in range direction. The offset in azimuth can be caused by an error in azimuth timing of the master acquisition.
- Undetected non-linear displacements: This is the most critical problem of PSInSAR products. It is possible that displacement signal leaks to other terms, in particular to estimated atmospheric signal. This may occur in particular when there is no a priori knowledge on the expected displacement. Validation by the end-user can identify areas where this happens, and the OSP can then analyse the estimated atmospheric signal in more detail for such an area.

- Temporal "unwrapping errors": If the unwrapping is mainly based on a temporal displacement model, then it can happen that the measurements are unwrapped incorrectly due to this model assumption. For example, if a PS point is stable during the first two years, and then subsides with a linear rate for eight years, it is likely that the data acquired during the first two years are "lifted" to best fit the linear model. This is particularly important when there are temporal gaps in the data. Validation by the end-user can identify areas where this happens, and the OSP can then fine-tune the processing.
- Mis-detection of PS: The delivered results may contain estimates at points that are not PS points. For example, such points could be side lobes of strong scatterers, or points that by random chance have a phase that well fits the displacement model. During a comparison with ground-truth data it must be made sure such points are not included.
- Outliers: The delivered product can contain outliers. Such estimated points can be filtered out partly using, e.g., a spatial smoothness criterion, but some may still be present. During a comparison with ground-truth data it must be made sure such points are not included. The overall density in general is affected by setting a threshold parameter. A more restrictive setting will eliminate some outliers, but will also reduce the density of the product.
- Platform position errors: As for the conventional InSAR products, individual interferograms may be contained with a regular phase pattern due to orbit errors. Such errors can be generally identified by analysis of the residual phase after correction of the estimated parameters for topography and displacement. Such errors can be corrected, which implies that the estimated displacement field is detrended, or can be left uncorrected, assuming there are no interferograms with large errors due to this source. The service validation report should specify the approach.

The validation plan allows correction of these biases, and offers a way to compare the ground-truth data with the PSInSAR measurements.

2.3.2.2 PSInSAR product accuracy assessment

- ▶ The product validation is carried out by the End-User.
- ▶ The service validation report must include a realistic expectation for the difference between the PSInSAR measurement with the ground-truth data, and a clear assessment of the discrepancy between the geodetic ground data (provided by the end user or any other source) and the radar measurement. A discussion must be provided if this comparison exceeds the expectations.

Related to the problems identified in the previous section, here a validation protocol for the accuracy of the PSInSAR product is given which is aimed at overcoming the common problems with the comparison using ground-truth data, see also Table 4.

- Planimetric (horizontal) accuracy: External data, such as an ortho-rectified aerial photo or cartographic data layers, or material available via the internet should be used to check the planimetric accuracy. The consistency between the location and/or absence of the PS and the presence of expectedly temporally coherent targets such as buildings or bare soils. For PSInSAR products processed without using ground data, a constant offset of up to a couple of hundreds of meters in the PS positions is possible. This is mainly due to the unknown absolute height of a reference point. To a lesser extent, timing errors in range and azimuth direction can cause errors in the geo-localization of the PS points. In such cases an a posteriori correction must be carried out for the estimated heights and georeferenced positions.
- Planimetric (horizontal) precision: An assessment of the planimetric precision of the georeferenced PS positions can be performed using cartographic material and ortho-photos. Such assessments are limited by the different nature of both sources of information.

- **Topometric (height) accuracy:** If the height of the product is estimated, a measure should be provided how accurately this is done. This is important, because the accuracy of the geo-referencing is related to the accuracy of the estimated height of the PS points.
- **Displacement rate accuracy:** Assuming a linear displacement rate is estimated, a bias of the displacement field can be estimated by comparison to ground-truth data. The estimated rates should be corrected for this bias to account for instability of the reference point. The estimated displacement rates can be compared regarding shape and maximum of deformation with ground-truth data. The choice for the location of the reference point should be checked.
- **Displacement rate precision:** The precision of the estimated rates can be assessed by comparison of the estimated rates with the displacement rates of the closest by ground-truth points, taking into account the known error sources described above.
- **Displacement precision:** The data corrected for all biases can be validated using a comparison of the estimates with available time series of ground-truth data at nearby locations, taking into account the problems noted above. The RMSE of the difference should be included in the service validation report. In case of non-linear deformation, the time series from the two techniques should be compared visually to validate the result, in particular the dates and amplitude of specific events in the series. Qualitative difference must be mentioned in the validation report. Such comparison is however limited by the reduced number of time series provided (respectively to the number of point provided with deformations rates). Figure 3 shows an example of such a validation.

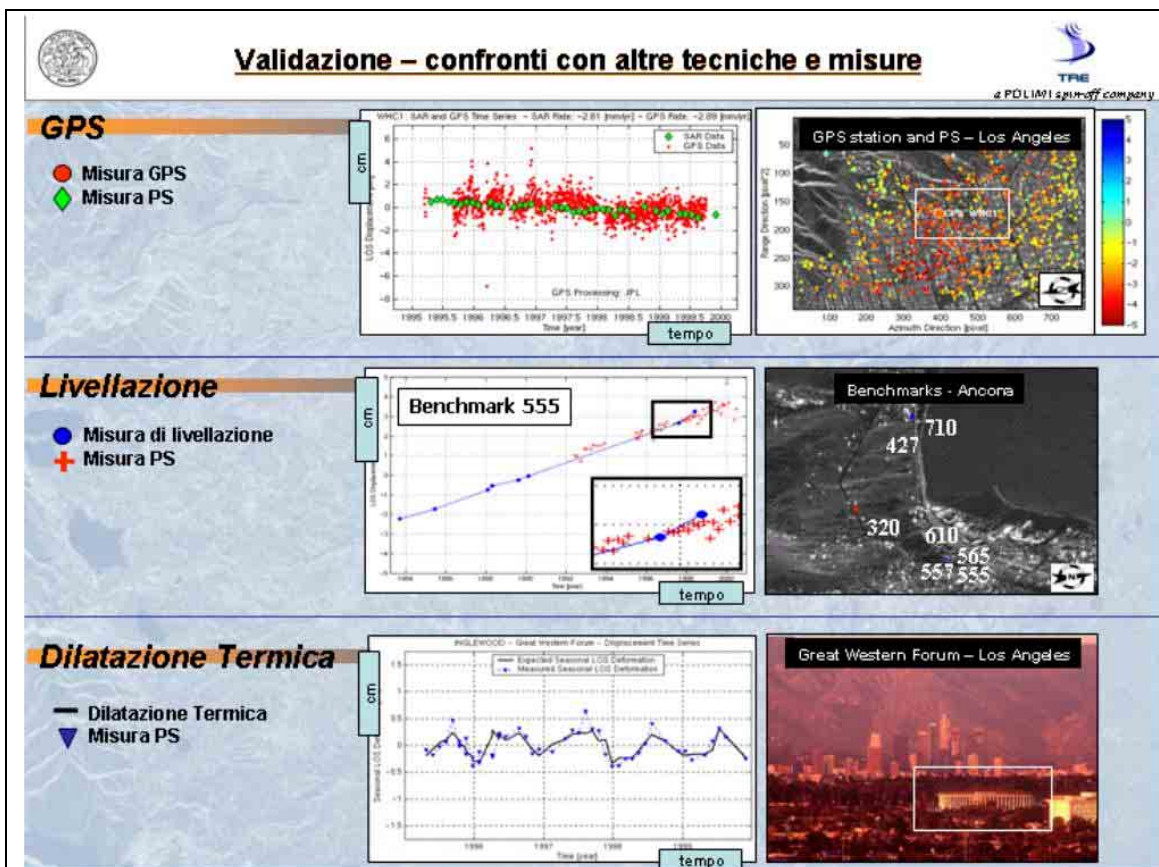


Figure 3: Examples of product validation for the PSInSAR measurements using external data such as GPS, levelling, and temperature information.

2.3.2.3 Terrafirma shop window

A specific open section of the Terrafirma website should be dedicated to a showcase of a wide range of such validation examples (which number could be increased during the project itself), in order to constantly reinforce the confidence of the public and potential users into the performances of InSAR measurements.

2.4 Validation plan for Level 1 products

Table 1 shows the validation plan for level 1 products and corrective actions.

Table 1: Validation for Level 1 products.

VALIDATION STEP	VAC	USER	CUG	DELIVERABLE	DEADLINE FOR REPORT DELIVERY	CORRECTIVE ACTION
Ordering		X		Appendix 9.1	From End-User to OSP: before production beginning Final version: product delivery + 1 month	- Correction of the characteristics of the data selection. - Analysis of the causes of the none conformity
Input data	X			Appendix 9.1	Before production	- Improvement of the data set (rejection of unreliable data, new selection)
Validation data		X	X	Appendix 9.1	Before validation	
Production – format	X	X		Appendix Error! Reference source not found. , 9.3, or 9.4	OSP : provided when product is delivered End-User : product delivery + 1 month	- Correction of the characteristics of the data selection. - Analysis of the causes of the none conformity
Production - accuracy	X	X	X	Appendix Error! Reference source not found. , 9.3, or 9.4	Product delivery + 3 months	- No corrective action for individual test site
Delivery		X		Appendix 9.1	End-User : Product delivery + 1 month	- Corrections in the OSP production / delivery system

In addition to the mentioned individual corrections, the compilation and analysis of the whole set of reports by the *Terrafirma* team should allow to identify systematic defects not envisaged in this document and to propose corrections in order to optimise the level 1 service.

2.5 Summary of the validation procedure for H1 products

The time diagrams given in Table 2, Table 3, and Table 4 provide a summary of the responsibilities of each involved party of service, process, and product validation, respectively.

Table 2: Time diagram for Service Validation (who, what, when, etc.)

TIME	OSP	END-USER
↓		Express interest; provide OSP with type of measurement (differential interferogram, PSInSAR, etc.), the geographic coordinates of area of interest, and the time period of interest.
	Send End-User the (signed by OSP) <i>Service Level</i>	

	Agreement and request it to be returned.	
		Return signed <i>Service Level Agreement</i> to OSP.
	Send copy of the signed <i>Service Level Agreement</i> to the Administrative Prime within seven days of signing for compilation into the <i>Terrafirma</i> dossier C7: <i>Service Level Agreements</i> .	
	Check data availability/ assess possibility of requested type of measurement. Provide the user with a list of proposed scenes, preview amplitude image. Write relevant introduction section of service validation report and send this to the user.	
		Confirm proposed area, time frame.
	Order data; Notify the user in case of delays or unavailability of proposed data, and assess possibility of success based on new constraints. Write relevant section of service validation report.	
		If notified of data change, confirm/cancel processing.
	Start processing. Ask user for relevant data if appropriate (reference map, ground truth data, ground control points, stable areas, expected deformation, etc.) Include a non-disclosure agreement if so desired by the user.	
		Provide requested data for calibration of geo-referencing/ displacement estimates. Inform OSP whether data can be used for validation and externally published.
	Write relevant section of service validation report (add standardised tables provided in appendix 9.1).	
	Perform the agreed type of processing (making use of the QC document of the OSP) and create the agreed product. (Analyse artefacts due to atmospheric signal, unwrapping, etc.; Calibrate planimetric and topometric accuracy using ground truth data.)	
	Fill out relevant table for service validation report (see for InSAR Appendix Error! Reference source not found. ; for stacked InSAR Appendix 9.3; for PSInSAR Appendix 9.4).	
	Send user up-to-date service validation report and deliverable product.	
	Send user relevant tables and request completion (see for InSAR Appendix Error! Reference source not found. ; for stacked InSAR Appendix 9.3; for PSInSAR Appendix 9.4).	
		Complete the relevant table and return to the OSP. Indicate problems with the delivered product, such as non-conformity to the agreed standard and request an update.
	If the user indicated non-conformity, update the product and the processing chain. Deliver a new product in acceptable time to the user.	
		Confirm correct delivery or re-iterate to improve the product.
	Send user (appendix 9.1) and request completion.	
		Return (appendix 9.1) to the OSP.
	Add (appendix 9.1) to the service validation report and send the complete report to the user on the agreed way (electronic/regular mail).	
	Send Administrative Prime a key summary, see Table 5.	

Table 3: Time diagram for Process Validation (who, what, when, etc.)

TIME	OSP	DLR	ADMINISTRATIVE PRIME
↓	Express interest to Administrative Prime.		
			Contact DLR with details on the process validation request.
		Confirm to OSP and Administrative Prime. Request specific audit information from the OSP.	
	Send requested audit information to DLR.		
		Perform the audit; Contact OSP for more information if required. Write relevant process validation report section. If negative validation, contact Administrative Prime.	
		Contact OSP for QC document if positive audit validation step.	
	Send requested QC documentation to DLR.		
		Perform validation; Contact OSP with questions. Write relevant process validation report section. If negative validation, contact Administrative Prime.	
		Contact OSP for 3-5 page description of the algorithm, if positive QC validation.	
	Send requested algorithm documentation to DLR.		
		Validate the algorithm based on the description. Contact the OSP to clarify the documentation if required. Write relevant process validation report section. If negative validation, contact Administrative Prime.	
		Contact the OSP to perform test area processing (default PSIC4 area). Act as end-user.	
	Act as <i>Terrafirma</i> OSP: react on request by user. Provide user with list of data, etc. see also Table 2.		
		Act as user, see also Table 2.	
	Order data from Administrative Prime.		
			Provide test data to OSP and DLR (if not PSIC4 area).
	Process the data. Deliver <i>Terrafirma</i> level 1 product to DLR conforming to the standards, including service validation report.	Perform a cross-processing if necessary using the data obtained from the Administrative Prime.	
		Validate the delivered service. Write relevant process validation report section and executive summary.	
		Send process validation report to OSP and	

		executive summary to the administrative prime.	
			Admit/decline the OSP to <i>Terrafirma</i> based on the executive summary. Update website and new documentation. Archive the executive summary.
	Accept decision or submit protest to the Administrative Prime.		

Table 4: Time diagram for Product Validation (who, what, when, etc.). It is assumed that a level 1 product is available, together with ground-truth data. The End-User performs the validation. However, the OSP may be involved too, for example to make sure relevant ground-truth data was used during processing.

TIME	END-USER	OSP
↓		Deliver product.
	Planimetric accuracy: use ground-truth data such as orthophoto, topographic material, etc. to assess the accuracy of the geo-referencing of the delivered product. Correct the product for the estimated bias in both directions.	
	Planimetric precision: use the ground-truth data to assess the precision of the georeferenced points.	
	Topometric (height) accuracy: use the ground-truth data to assess the difference between the delivered height estimates at the PS points and that of the ground-data. Note that this is not a quantitative error, because the PS points are located elsewhere than the ground data.	
	Topometric (height) precision: not planned to be validated. For PSInSAR, the height is that of the PS points, which location is difficult to compare with ground-truth data because the origin of the radar reflection is unknown. Possibly, a histogram of the estimated height, or DEM error if a good DEM is available, could give insight in the precision of the estimated heights. Note that the planimetric precision is related to the precision of the estimated height.	
	Deformation shape: comparison with ancillary data map or point data related to the motion mechanism or consequences (interpolated deformations maps, damages inventories, hazard maps, mine maps, piezometric data, ...): is the geometric shape of the detected deformation consistent with the a priori knowledge?	
	Deformation accuracy: estimate a bias of the delivered displacement (rates) due to instability of the reference point used during processing. Correct the estimated displacement (rates) for this bias.	
	Deformation precision: assess the difference between the <i>Terrafirma</i> displacement measurements and the ground-truth data and contribute this to errors in either one. Compare rates and PS time-series. In cooperation with the OSP, contribute the errors in the product to, e.g., incorrectly estimated atmospheric signal, uncompensated orbit errors. Allow for improvement of the delivered product using this knowledge. Provide qualitative examples and quantitative measures of the geological relevance of the level 1 product.	
	Include conclusions in a section of the Service Validation report. Make this available to the OSP.	
		Contact Administrative Prime to publish validation as show case on website, if appropriate.

3 PRODUCT VALIDATION OF LEVEL 2 PRODUCTS

This level 2 contains the comparison of InSAR measurements with external layers of relevant data. As summarised in the T2-U6 “user standards handbook” dossier, the main types of auxiliary data that are likely to be incorporated into Level 2 of the service portfolio are:

- I. Geological data, 2D and 3D
- I. Lithology
- I. Superficial thickness
- I. Mineralogical properties
- I. Local borehole data
- I. Geotechnical properties
- II. Water table
- II. Soil moisture deficit/temporal and spatial rainfall distribution
- II. Spring lines
- II. Well locations
- II. Drainage patterns
- II. Hydrogeological properties
- III. Extraction records
- III. Quarries/underground works
- IV. Topographic data
- V. RS optical images

The detailed list of auxiliary data is given in section 4.8 of the Service Portfolio Specifications dossier (S5), which specifies when their usage is appropriate

The level 2 is therefore a “causal” product, where observed deformation phenomenon is tentatively interpreted by geological surveys (or possibly civil engineering companies). The validation procedure therefore relies mostly on expertise from the Geological Surveys, and is strongly dependent on the availability of these external data layers. The validation of the interpretation cannot be standardised as it relies on the relevance and accuracy of the external data available for a specific deformation event. As stated in the T2-U6 dossier, most of the auxiliary information is *geologic/hydrogeologic* in nature. Much of this information is thus interpretative in nature, based on limited data. Consequently, it is not possible for ‘standards’ to be applied to much of this information because the way interpretations are carried out is not conducive to standardisation. Because standardisation in many aspects of geological/hydrogeological interpretation is relatively difficult, little progress has been made towards standardisation internationally. At a national level, geological surveys are frequently the main organisation carrying out this type of work. Consequently, they often set the standard, in so far as such standards are applied at all. When no standard is available, the validation procedure cannot be defined on a strict basis. The validation procedure for the level 2 products will be refined in the second phase of the project when a sufficient amount of demonstration cases reaching this level will be available. The minimum required is a verification/ approval system of the interpretative conclusions summarised in a detailed report produced by the involved partners. Respective Geological Surveys could interact on a national coverage basis.

3.1 Landslide Inventory Product (LSI)

The LSI product is a variant based upon the level 2 products. It maps unstable slopes over whole basins, incorporating SAR data from the archive. LSI products are made from H1 products, and utilise auxiliary data including geological, in situ, and Very High Resolution optical imagery.

Validation is performed by the End-User. No formal general validation is possible, see section 3. However, for the LSI product, a comparison should be made between the estimates in the LSI product and the location and extent of known landslides.

3.2 Landslide Monitoring Product (LSM)

The LSM product is a variant based upon the level 2 products. It focuses on the ongoing InSAR monitoring of specified slopes, incorporating data from new programmed acquisitions. LSM products are made from both LSI and M1 products, and utilise auxiliary data including geological, in situ, and Very High Resolution optical imagery.

Validation is performed by the End-User. No formal general validation is possible, see section 3. However, general cross-validation strategies exist in literature which could be applied.

4 PRODUCT VALIDATION OF LEVEL 3 PRODUCTS

The level 3 products include mostly the modelling of the observed phenomenon. This allows:

- A better understanding of the mechanisms and it identifies, and quantifies, the influence of the most important parameters involved.
- Prediction of the amount of subsidence that can be expected in a site concerned by a natural or anthropogenic effect. For example, models are commonly used in the mining industry to forecast the surface deformations which could result from an intensive extraction activity. This information is important to assess the potential damages to the overlying buildings, and also to assess the impact upon flooding risks.

However, the modelling process cannot be performed systematically, but is rather a project-based product involving mainly geological surveys and civil engineering companies. It requires a priori knowledge of the specifics of the test site and of the mechanisms involved.

Even more than for a level 2 product, the validation of a level 3 product can not be thought as a standardised process, but rather is an a posteriori control of the output. The quality of the model can be evaluated by its ability to reproduce the observed past deformations, and when long term monitoring is possible, by its ability to forecast the ongoing phenomena.

5 VALIDATION OF REFERENCE DATA

- ▶ This step of the validation is carried out by the End-User (or CUG member).
- ▶ Service validation report: appendix 9.1.

Format and accuracy of EO data and ancillary ground data are used during processing and for validation. Appreciation of the quality and relevance of these data is to be included in the validation report, see appendix 9.1.

The ground based data which is used for the validation processing can be from a different nature in relation with the mechanism of the deformation. The relevance of the ground data to the observed deformation is partly an expertise matter and a standard cannot be defined. Therefore, the End-User (or CUG member carrying out the validation) has to estimate the relevance of the data set for the validation.

5.1 Approach for getting endorsement of validation from key external user-bodies

► This step of the validation is carried out by the Product Validation Workgroup.

The reference data can be used as *product validation* input data, in which case it is very important to know its quality, because it will be used as ground truth. These data are either already held by the Product Validation Workgroup, or will be collected by them during validation campaigns. The Workgroup will nominate the sites for their campaigns, and so nominate according to the data requirement and availability.

It is possible that existing ground truth data cannot be obtained easily because, for example, the original measurements are owned by a private company, it is confidential or sensitive information, or because an organisation does not want to share the data or is not allowed to do so by law. In such cases, the Product Validation Workgroup could try to obtain access by explaining the background of Terrafirma and the importance of ground truth data for validation, and that the validation will be discussed with the holder of the data, without sharing the data or usage for any other party. However, it should be possible to use, for example, anonymous time series for marketing purposes. As an alternative, it could also be offered that the holder of the ground truth data obtains access to the InSAR results and partly or also performs a validation.

6 VALIDATION OF NEW PRODUCTS AND PROVIDERS

This section deals with the validation principles of new products, upgrades and evolving standards. It also states how to validate a new OSP that might approach the Administrative Prime to join the *Terrafirma* consortium.

6.1 New operational service provider (OSP)

► *Subject to funding approval*, this step of the validation is carried out by DLR with help of the administrative prime and in collaboration with the new OSP.

In case a new OSP wants to join the project consortium, it will be guaranteed that the provided services are of a comparable quality as those delivered by the existing OSPs, regarding the processing procedures and conformation to the standards. A new OSP will be validated using the procedures defined in this document, see section 2.2.2. Therefore, the potential OSP must get access to this document and the product specification.

The validation will be carried out by DLR and be administered by DLR and the Administrative Prime.

A process validation report will be provided to the potential OSP which will state conclusions about the performed validation and any shortcomings that may have been detected.

If the validation is positive, the Administrative Prime will invite the VAC as a new OSP in to *Terrafirma*.

6.2 Software upgrades

► This step of the validation is carried out by the OSP.

The OSP has to make sure that software upgrades do not degrade the quality of the delivered products and that the products maintain to adhere to the agreed standards. The OSP is responsible for this validation and in the validation report the software version is to be reported.

The OSP needs to have a configuration control in place to make sure that it can return to a previous version of the software. (Moreover, configuration monitoring needs to remain in place, a log of the version, and the software version needs to be included in the validation report.)

The OSP needs to perform a cross-comparison of the results of the previous and the current version, preferably using the PSIC4 data set. This test needs to be documented in an internal upgrade report. If there is doubt with regard to adherence to the standards or the quality of the product after the upgrade, the OSP can request DLR to validate the upgraded software in the same way as the existing software, based on the upgrade report of the OSP. The upgraded software is considered to be validated if the previous version was validated, and the upgrade report does not show deterioration of the quality of the product.

6.3 New or updated standards

► This step of the validation is carried out by the OSP.

When new standards are specified in the S5 dossier, they need to be implemented by the OSP and validated. For example, evolution is foreseen in the definition of:

- Projection system:
 - Currently UTM is used for point data. The user may also select to have these data delivered in their own grid. Raster data is provided unprojected as latitude/longitude.
 - INSPIRE recommends the ETRS89 datum and GRS80 ellipsoid for georeferencing, using the Transverse Mercator projection for scales larger than 1:500,000 and the Lambert Conformal Conic projection for scales smaller than 1:500,000.
- Raster file:
 - Currently GeoTIFF.
 - INSPIRE recommended formats are HDF-EOS, BIIF 12087-5 and CEOS.
- PS point database:
 - Currently dBase IV (.dbf) format.
 - ISO 19125 standard should be adopted once it reaches full International Standard status, and is supported by GIS software.
- Metadata:
 - Currently a text file providing the product definition parameters.
 - ISO 19125 standard should be adopted once it reaches full International Standard status, and is supported by GIS software.

Validation of these new standards is to be done similarly as is done for the existing standards. The OSP and the End-User perform this task by checking whether the delivered data conforms to the standard. If the delivered data does not conform to the standard, the OSP has to make sure the product will conform in future, and for the delivered product if so desired by the end-user.

6.4 New products

► This step of the validation is carried out both by the VAC and the end-user. Definition of validation procedures by DLR.

For any new product that is defined in the S5 dossier, it is required that this service validation protocol includes them. At that time, it must be defined which parameters need to be validated and which need to be included in the service validation report. The VAC and the end-user will perform the validation in a similar fashion as for the H1 product.

A definition of a proposed new product will be submitted to DLR, via the administrative prime. DLR will integrate the new product in to the next update version of the C5 (this) document.

6.4.1 Hybrid technologies products

An emerging level 1 product is based on hybrid technologies, in particular CRInSAR and CATInSAR, which is nearing operational status. The general validation principles and procedures for these technologies are identical to the general procedures for the level 1 products described above. Thus, these procedures are applied to these products as well.

In addition, the hybrid technologies can be validated using PSInSAR, and vice-versa, in the respect that the estimated deformations of a joint analysis should be internally consistent. In some cases, especially in the early development stages of these techniques, external measurements (levelling or GPS) of the position and deformation of these artificial targets should be made, and used during the validation. The outcome of this comparison can be used as PRODUCT validation for the hybrid technologies and the PSInSAR products.

7 ACCESS, DISTRIBUTION AND AVAILABILITY OF VALIDATION DOCUMENTS

This section describes the availability of several reports defined in this document. This is particularly important for reports containing sensitive information on algorithms or ground movements. Table 5 gives an overview of the bodies that have access to these documents.

Table 5: Access, distribution, and availability of validation reports to project partners, ESA, management (NPA), validation workgroup, and/or external parties. Access defines the bodies that are directly involved and have unrestricted access to the document. Distribution pertains to the body responsible for distribution and to the media used for distribution. Availability defines who the report is available to.

REPORT	ACCESS	DISTRIBUTION	AVAILABILITY
<i>Software upgrade report</i>	Internal to the OSP	The OSP needs to archive it.	DLR can be granted confidential access if the OSP desires a process validation of a software upgrade.
<i>Service validation report</i>	OSP, End-User	The OSP provides the end-user with a service validation report. The OSP provides the Administrative Prime with a summary, at least containing the size of the area and number of data sets used, and any comments of the end-user that are important to the project, such as non-conformity of the product. Can be send in electronic form or on paper, per preference of the user.	The administrative prime makes available on request to ESA and the project partners the key summary.
<i>Process validation report</i>	DLR, (potentially new) OSP;	DLR provides the OSP with the process validation report via email. An electronic copy of the executive summary of the report is send to the Administrative Prime.	Executive summary is available via the Administrative Prime to a potential end-user, to ESA, and to the project partners.
<i>Product validation report</i>	CUG, OSP	Public show cases via world wide web. Sensitive information that cannot be distributed is not distributed.	Public show cases are generally available via the <i>Terrafirma</i> website, shop window. If prohibited by the provider of the ground truth data, the product validation report is confidential between the OSP and the

			end-user.
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8 SUMMARY AND CONCLUSIONS

This Service Validation protocol dossier defines the top-level approach for validation of the Terrafirma products and processes. An important distinction is between process validation and product validation. Process validation is performed by DLR and ensures that procedures are in place at each OSP which guarantee that consistent and reliable products are generated that conform to the agreed standards. Product validation is concerned with the geophysical meaning of the *Terrafirma* products, and is performed by the OSP in collaboration with the end-user or owner of ground truth data.

Terrafirma provides three product levels (1-3). Table 6 shows these levels, and additionally a level 0 product, and the parties involved in the validation. The production process for Level 0 and Level 1 products are validated using an agreed set of criteria, such as checking the planimetric and topometric accuracy using the confrontation with external topometric data (levelling or GPS). Level 2 and Level 3 products are delivered and validated on a site specific, non standard, basis.

Table 6: Parties involved in the production and validation process.

PRODUCT	PRODUCTION	VALIDATION	
<i>Level 0</i> Binary image or vector polygon to show service coverage	OSP	OSP End-User	
<i>Level 1</i> InSAR measurements only	OSP	OSP End-User	Auxiliary topometric Data (user + GS/CE)
			Comparison Aux. Data /INSAR (VAC + user + GS/CE)
<i>Level 2</i> Causal product (interpreted by Geological surveys and/or Civil Engineering companies).	Level 1+ GS/CE	End-User	Auxiliary Data (user + GS/CE)
			Interpretation analysis (GS/CE)
<i>Level 3</i> Modelled product (project-based product by Geological Surveys and/or Civil Engineering companies)	Level 2+ GS/CE	End-User	

9 APPENDICES VALIDATION REPORTS

The following sections provide tables that are to be included in the validation report for the level 1 products. Each product is validated by the VAC, and by the end-user upon delivery, using these tables. Section 9.1 shows the general standard tables included with each product. 9.3

9.1 General standard tables for the Service Validation Report

Table 7: Available input data for processing.

Product type:	
Location:	
Filled out by:	(OSP)

Date:			
Protocol	Standard	Conformity	Comments, e.g., tests applied, reason for non-conforming
1 – Satellite data set	ERS/ENVISAT/RADARSAT data. A list of the rejected acquisitions must be provided in the report.	√ / X	Number =
2 – Topographic information resolution	Topographic map/DEM has a resolution of 3 arc second or better.		DEM =
3 – Satellite state vectors	Precise satellite state vectors obtained from Delft University, DLR, or CNES DORIS orbits, or other. (usage not obligatory)	N/A	orbits =
4 – Ground-truth data for planimetric calibration (cartographic map/high resolution optical satellite data, etc.)	Product georeferenced position accuracy depends on the quality of the reference data and on the precision of the estimated height. Landsat ETM data is used by default unless higher quality data is available from the end-user.	N/A	data =
5 – Ground-truth data for displacement calibration	Ground truth information regarding stable regions for reference point location is required to calibrate the displacement map. Availability of time series and examples of the expected displacement pattern (breakpoints, etc.) will aid the processing.	N/A	data =

Table 8: Available ground-truth data for validation.

Product type:			
Location:			
Filled out by: End-User			
Date:			
Protocol	Standard	Relevancy	Correction decision
1 – layer data	Description: Source: Accuracy: Confidential: Provided to OSP at date:	√ / X	
	Description: Source: Accuracy: Confidential: Provided to OSP at date:		
	...		
2 – point data	Description: Source: Accuracy: Confidential: Provided to OSP at date:		

	Description: Source: Accuracy: Confidential: Provided to OSP at date:		
	...		

Table 9: Ordering/delivery

Product type: Location: Filled out by: End-User Date received: Date returned:			
Protocol	Standard	Conformity	Comments, e.g., tests applied, reason for non-conforming
1 – area of interest	Defined by end user:	√ / X	
2 – period of interest	Defined by end user :		
3 – delivery time	6 weeks		
4 – general comments on the ordering/delivery service			

9.2 Standard tables for the Service Validation Report: H1a - Conventional Differential InSAR Product

Table 10: H1a - Conventional Differential InSAR Product (OSP).

Product type: Conventional Differential InSAR Location: Filled out by: OSP Date:			
Protocol	Standard	√ / X <small>(Conform/ Non-conform)</small>	Comments e.g. tests applied, reason for non-conforming
1 - Processing Conventional differential InSAR			

1.1 – Uncompensated topography	Description and location of residual topographic effects on interferograms		Details: e.g... provide copy in separate floating section or table of this report.
1.2 – Platform position errors	Description and location of phase trends across the interferogram		Details:
1.3 – Atmospheric artefacts	Description and location of residual atmospheric effects on interferograms		Details:
1.4 – Correlation and coherence	Coherence image produced		
1.5 – Fourier filtering	Applied / not applied		
1.6 – Phase unwrapping	Applied / not applied		
2 – Product Resolution, accuracy, tolerances			
2.1 – Resolution			
2.1.1 – X, Y pixel size	16m or 25m		
2.1.2 – Displacement sampling	<0.28mm		
2.2 – Accuracy			
2.2.1 – X, Y accuracy	50m		
2.2.2 – Displacement accuracy	RMS at deformation maxima (cm)		
2.3 – Differential InSAR tolerances (recommendations for the selection of relevant interferograms)			
2.3.1 – Perpendicular baseline	<200m		
2.3.2 – Temporal separation			
Urban or Arid	<8 years		
Temperate rural environment	<70 days; 1 year for specific land covers		
Semi arid	<2 years		
2.3.3 – Atmospheric perturbations A	Areas of known or suspected uncompensated topography and/or atmospherically induced fringes are masked out from the Terrafirma InSAR product.		Details:
2.3.4 – Atmospheric perturbations B	To overcome measurement ambiguity due to the presence of atmospherically induced fringes, alternative data pairs must be processed and stacked (subject to data availability and interferogram quality).		Details:
2.3.5 – Coherence	InSAR measurements are provided only for coherent regions		
3 – Product data layers			
3.1 – SAR Amplitude image			
3.1.1 – Projection	UTM, Datum: ETRS89 Ellipsoid: GRS80		
3.1.2 – Data type	8-bit unsigned		
3.1.3 – Format	GeoTIFF		
3.1.4 – Georeference information	Integral GeoTIFF tags, Arc Info World file (.tfw) and text file of corner co-ordinates (.txg)		
3.1.5 – Colour table applied	Greyscale		
3.1.6 – Contrast stretch applied	Linear 1-99%		
3.1.7 – Null value	255		
3.2 – Fourier filtered differential interferogram			
3.2.1 – Projection	UTM, Datum: ETRS89 Ellipsoid: GRS80		utm zone:
3.2.2 – Data type	8-bit unsigned		
3.2.3 – Format	GeoTIFF		
3.2.4 – Georeference information	Integral GeoTIFF tags, Arc Info World file (.tfw) and text file of corner co-ordinates (.txg)		
3.2.5 – Colour table applied	Greyscale		

3.2.6 – Contrast stretch applied	None		
3.2.7 – Phase value range	1-100		
3.2.8 – Null value	255		
3.3 – Ground displacement map			
3.3.1 – Projection	UTM, Datum: ETRS89 Ellipsoid: GRS80		utm zone:
3.3.2 – Data type	32-bit float		
3.3.3 – Byte order	L-H (Little Endian, Intel)		
3.3.4 – Format	Simple array		
3.3.5 – Contrast stretch applied	None		
3.3.6 – Georeference information	Arc Info World file (.fw), text file of corner co-ordinates (.txg) and ERMapper (.ers)		
3.3.7 – Null value	-9999		
3.4 – Processing summary report <i>Report includes:</i>			
3.4.1 – Process Date			
3.4.2 – Software used			
3.4.3 – Version			
3.4.4 – Analysis type			
3.4.5 – Number of scenes used			
3.4.6 – Satellite data used			
3.4.7 – Scale			
3.4.8 – Georeference (X,Y) accuracy	Value=		
3.4.9 – Reference data used for georeference			
3.4.10 – H1a Dates used for interferogram			
3.4.11 – H1a Temporal separation			
3.4.12 – H1a Bperp			
3.4.13 – H1a Observations			
3.4.14 – H1a Uncompensated atmospherics			

Table 11: H1a - Conventional Differential InSAR Product (End-User).

Product type: Conventional Differential InSAR			
Location:			
Filled out by: End-User			
Date received:			
Date returned:			
Protocol	Standard	√ / X (Conform/ Non-conform)	Comments e.g. tests applied, reason for non-conforming
1 – Product data layers			
1.1 – SAR Amplitude image			
1.1.1 – Projection	UTM, Datum: ETRS89 Ellipsoid: GRS80		utm zone:
1.1.2 – Data type	8-bit unsigned		
1.1.3 – Format	GeoTIFF		
1.1.4 – Georeference information	Integral GeoTIFF tags, Arc Info World file (.fw) and text file of corner co-ordinates (.txg)		

1.1.5 – Colour table applied	Greyscale		
1.1.6 – Contrast stretch applied	Linear 1-99%		
1.1.7 – Null value	255		
1.2 – Fourier filtered differential interferogram			
1.2.1 – Projection	UTM, Datum: ETRS89 Ellipsoid: GRS80		utm zone:
1.2.2 – Data type	8-bit unsigned		
1.2.3 – Format	GeoTIFF		
1.2.4 – Georeference information	Integral GeoTIFF tags, Arc Info World file (.tfw) and text file of corner co-ordinates (.txg)		
1.2.5 – Colour table applied	Greyscale		
1.2.6 – Contrast stretch applied	None		
1.2.7 – Phase value range	1-100		
1.2.8 – Null value	255		
1.3 – Ground displacement map			
1.3.1 – Projection	UTM, Datum: ETRS89 Ellipsoid: GRS80		utm zone:
1.3.2 – Data type	32-bit float		
1.3.3 – Byte order	L-H (Little Endian, Intel)		
1.3.4 – Format	Simple array		
1.3.5 – Contrast stretch applied	None		
1.3.6 – Georeference information	Arc Info World file (.tfw), text file of corner co-ordinates (.txg) and ERMapper (.ers)		
1.3.7 – Null value	-9999		
1.4 – Processing summary report <i>Report includes:</i>			
1.4.1 – Process Date			
1.4.2 – Software used			
1.4.3 – Version			
1.4.4 – Analysis type			
1.4.5 – Number of scenes used			
1.4.7 – Scale			
1.4.8 – Georeference (X,Y) accuracy	Value=		
1.4.9 – Reference data used for georeference			
1.4.10 – H1a Dates used for interferogram			
1.4.11 – H1a Observations			
1.4.12 – H1a Uncompensated atmospheric			
1.4.13 – general comment on the product			

9.3 Standard tables for the Service Validation Report: H1b - Stacked differential InSAR Product

Table 12: H1b - Stacked differential InSAR Product (VAC).

Product type: Stacked Differential InSAR

Location:

Filled out by: End-User			
Date received:			
Date returned:			
Protocol	Standard	√ / X (Conform/ Non-conform)	Comments e.g. tests applied, reason for non-conforming
1 - Processing stacked differential InSAR			
1.1 – Uncompensated topography	Description and location of residual topographic effects on interferograms		Details:
1.2 – Platform position errors	Description and location of phase trends across the interferogram		Details:
1.3 – atmospheric artefacts	Description and location of residual atmospheric effects on interferograms		Details:
1.4 – Correlation and coherence	Coherence image produced		
1.5 – Fourier filtering	Applied / not applied		
1.6 – Phase unwrapping	Applied / not applied		
2 – Product Resolution, accuracy, tolerances			
2.1 - Resolution			
2.1.1 – X, Y pixel size	16m or 25m		
2.1.2 – Displacement sampling	<0.28mm		
2.2 – Accuracy			
2.2.1 – X, Y accuracy	50m		
2.2.2 – Displacement accuracy	RMS at deformation maxima (cm)		
2.3 – Differential InSAR tolerances (these values are recommendations for the selection of the more relevant interferograms)			
2.3.1 – Perpendicular baseline	<200m		
2.3.2 – Temporal separation			
Urban or Arid	<8 years		
Temperate rural environment	<70 days; 1 year for specific land covers		
Semi arid	<2 years		
2.3.3 – Atmospheric perturbations A	Areas of known or suspected uncompensated topography and/or atmospherically induced fringes are masked out from the Terrafirma InSAR product.		
2.3.4 – Atmospheric perturbations B	To overcome measurement ambiguity due to the presence of atmospherically induced fringes, alternative data pairs must be processed and stacked (subject to data availability and interferogram quality).		
2.3.5 – Coherence	InSAR measurements are provided only for coherent regions		
3 – Product data layers			
3.1 – Reference SAR amplitude image			
3.1.1 – Projection	UTM, Datum: ETRS89 Ellipsoid: GRS80		utm zone:
3.1.2 – Data type	8-bit unsigned		
3.1.3 – Format	GeoTIFF		

3.1.4 – Georeference information	Integral GeoTIFF tags, Arc Info World file (.tfw) and text file of corner co-ordinates (.txg)		
3.1.5 – Colour table applied	Greyscale		
3.1.6 – Contrast stretch applied	Linear 1-99%		
3.1.7 – Null value	255		
3.2 – Fourier-filtered stacked interferogram			
3.2.1 – Projection	UTM, Datum: ETRS89 Ellipsoid: GRS80		utm zone:
3.2.2 – Data type	8-bit unsigned		
3.2.3 – Format	GeoTIFF		
3.2.4 – Georeference information	Integral GeoTIFF tags, Arc Info World file (.tfw) and text file of corner co-ordinates (.txg)		
3.2.5 – Colour table applied	Greyscale		
3.2.6 – Contrast stretch applied	None		
3.2.7 – Phase value range	1-100		
3.2.8 – Null value	255		
3.3 – Ground displacement map	Provided / not provided	P/NP	
3.3.1 – Projection	UTM, Datum: ETRS89 Ellipsoid: GRS80		utm zone:
3.3.2 – Data type	32-bit float		
3.3.3 – Byte order	L-H (Little Endian, Intel)		
3.3.4 – Format	Simple array		
3.3.5 – Contrast stretch applied	None		
3.3.6 – Georeference information	Arc Info World file (.tfw), text file of corner co-ordinates (.txg) and ERMapper (.ers)		
3.3.7 – Null value	-9999		
3.4 – Processing summary report <i>Report includes:</i>			
3.4.1 – Process Date			
3.4.2 – Software used			
3.4.3 – Version			
3.4.4 – Analysis type			
3.4.5 – Number of scenes used			
3.4.6 – Satellite data used			
3.4.7 – Scale			
3.4.8 – Georeference (X,Y) accuracy	Value =		
3.4.9 – Reference data used for georeference	Details:		
3.4.10 – H1b Number of scenes in stack			
3.4.11 – Type of stacking carried out			
3.4.12 – Observations			
3.4.13 – Uncompensated atmospheric			

Table 13: H1b Product Data Layers (END USER/CUG).

Product type:	Stacked Differential InSAR		
Location:			
Filled out by:	End-User		
Date received:			
Date returned:			
Protocol	Standard	√ / X	Comments e.g. tests applied, reason for non-conforming
1 – Product data layers			
1.1 – Reference SAR amplitude image			
1.1.1 – Projection	UTM, Datum: ETRS89 Ellipsoid: GRS80		utm zone:
1.1.2 – Data type	8-bit unsigned		
1.1.3 – Format	GeoTIFF		
1.1.4 – Georeference information	Integral GeoTIFF tags, Arc Info World file (.tfw) and text file of corner co-ordinates (.txg)		
1.1.5 – Colour table applied	Greyscale		
1.1.6 – Contrast stretch applied	Linear 1-99%		
1.1.7 – Null value	255		
1.2 – Fourier-filtered stacked interferogram			
1.2.1 – Projection	UTM, Datum: ETRS89 Ellipsoid: GRS80		utm zone:
1.2.2 – Data type	8-bit unsigned		
1.2.3 – Format	GeoTIFF		
1.2.4 – Georeference information	Integral GeoTIFF tags, Arc Info World file (.tfw) and text file of corner co-ordinates (.txg)		
1.2.5 – Colour table applied	Greyscale		
1.2.6 – Contrast stretch applied	None		
1.2.7 – Phase value range	1-100		
1.2.8 – Null value	255		
1.3 – Ground displacement map			
1.3.1 – Projection	UTM, Datum: ETRS89 Ellipsoid: GRS80		utm zone:
1.3.2 – Data type	32-bit float		
1.3.3 – Byte order	L-H (Little Endian, Intel)		
1.3.4 – Format	Simple array		
1.3.5 – Contrast stretch applied	None		
1.3.6 – Georeference information	Arc Info World file (.tfw), text file of corner co-ordinates (.txg) and ERMapper (.ers)		
1.3.7 – Null value	-9999		
1.4 – Processing summary report			
<i>Report includes:</i>			
1.4.1 – Process Date			
1.4.6 – Satellite data used			
1.4.7 – Scale			
1.4.8 – Georeference (X,Y) accuracy	Value =		
1.4.9 – Reference data used for georeference			

1.4.10 – H1b Number of scenes in stack			
1.4.11 –Type of stacking carried out			
1.4.12 – Observations			
1.4.13 – Uncompensated atmospheric			
1.4.14 - General comment on the product			

9.4 Standard tables for the Service Validation Report: H1c - PSInSAR Product

Table 14: Conformity to the product standards (OSP). This checklist is used to make sure that the delivered product conforms to the standards. The End-User is to perform product validation using all available ground-truth data.

Product type:	PSInSAR		
Location:	Marseille/Gardanne, France		
Filled out by:	B. Kampes, DLR		
Date:	July 17, 2005		
Protocol	Standard	Conformity	Comments, e.g., tests applied, reason for non-conforming
1 - Processing PSInSAR			
1.1 –Reference PS			
1.1.1 – Location	In stable area near displacement of interest		X= Y= height=
1.1.2 – Calibration	Estimate bias in the estimated displacement rates using ground-truth and correct.		Correction applied = (mm/yr);
1.2 – Atmospheric perturbations	Minimised within image using the (possibly temporally filtered) residual phase.		RMS Value = (mm/yr) not measured
1.3 – Platform position errors	OSP responsible for correction if deemed necessary		
2 - Resolution, accuracy, tolerances			
2.1 - Resolution			
2.1.1 –Pixel size during processing	nominal size		
2.1.2 – Displacement sampling	0.1mm/year		
2.2 – Accuracy			
2.2.1 – Absolute X, Y accuracy	15m		RMS value = (m) not measured; is within spec.
2.2.2 – Relative X, Y accuracy	+/-5m east/west +/-2m North/south		RMS value = (m) not measured; is within spec.
2.2.3 – Displacement precision	+/-0.1mm/year		RMS Value = (mm/yr) (provided by VAC)
2.2.4 – Displacement accuracy	General case		RMS value = (mm/yr) not measured; is within spec.

	Non-linear deformation		Agrees/does not agree (comparison with ground data points)
	Agreement with qualitative information		
2.3 – Tolerances			
2.3.1 – Number of images analysed	>20		Number =
2.3.2 – PS density	>/= 5 PS/km ²		Density value =
2.3.3 – Time series delivered	not for all estimated and delivered points a time series can be produced		Number =
2.3.3 – Time series location	Locations should agree with end user demand)		
3 – Product data layers			
3.1 – Reference multi-image reflectivity map (MIR) image			
3.1.1 – Projection	UTM, Datum: ETRS89 Ellipsoid: GRS80		utm zone:
3.1.2 – Data type	8-bit unsigned		
3.1.3 – Format	GeoTIFF		
3.1.4 – Georeference information	Integral GeoTIFF tags, Arc Info World file (.tfw) and text file of corner co-ordinates (.txg)		
3.1.5 – Colour table applied	Greyscale		
3.1.6 – Contrast stretch applied	Linear		
3.1.7 – Null value	255		
3.1.8 – Resolution	25 m x 25 m		
3.2 – Raster of interpolated average annual displacement rates			
3.2.1 – 32-bit floating point raster			
3.2.1.1 – Projection	UTM, Datum: ETRS89 Ellipsoid: GRS80		
3.2.1.2 – Data type	32-bit float		
3.2.1.3 – Byte order	L-H (Little Endian, Intel)		
3.2.1.4 – Format	Simple array		
3.2.1.5 – Georeference information	Arc Info World file (.tfw), text file of corner co-ordinates (.txg) and ERMapper (.ers)		
3.2.1.6 – Null value	-9999		
3.2.1.7 – Resolution	25 m x 25 m		
3.2.2 – GeoTIFF raster			
3.2.2.1 – Projection	UTM, Datum: ETRS89 Ellipsoid: GRS80		utm zone:
3.2.2.2 – Data type	24-bit composite RGB		
3.2.2.3 – Byte order	N/A		
3.2.2.4 – Format	GeoTIFF		

3.2.2.5 – Georeference information	Integral GeoTIFF tags, Arc Info World file (.tfw) and text file of corner co-ordinates (.txg)		
3.2.2.6 – Colour table applied	Rainbow: Red-Orange-Yellow-Green-Cyan-Blue		
3.2.2.7 – Contrast stretch applied	Linear, min –5 mm/year, max +5 mm/year		
3.2.2.8 – Null value	255,255,255		
3.2.2.9 – Resolution	25 m x 25 m		
3.3 – Table of PS average annual displacement rate <i>Table includes:</i>	dBase IV (.DBF)		
3.3.1 – Code	PS unique identifier. The reference point is coded "REF".		
3.3.2 – Northing	UTM, Datum: ETRS89 Ellipsoid: GRS80		
3.3.3 – Easting	UTM, Datum: ETRS89 Ellipsoid: GRS80		
3.3.4 – Height	Retrieved PS height relative to reference point (m)		
3.3.5 – Displacement rate	Average annual displacement rate (mm/year)		
3.3.6 – Coherence	Connection coherence (quality indicator)		
3.3.7 – Range	SAR image range pixel		
3.3.8 – Azimuth	SAR image azimuth pixel		
3.3.9 – Standard deviation	Standard deviation of average annual displacement rate due to uncompensated atmospheric error (mm/year)		
3.4 – Table of PS time series <i>Table includes:</i>	dBase IV (.DBF)		
3.4.1 – Code	PS unique identifier. The reference point is coded "REF".		
3.4.2 – Northing	UTM, Datum: ETRS89 Ellipsoid: GRS80		
3.4.3 – Easting	UTM, Datum: ETRS89 Ellipsoid: GRS80		
3.4.4 – Height	Retrieved PS height relative to reference point (m)		
3.4.5 – Displacement rate	Average annual displacement rate (mm/year)		
3.4.6 – Coherence	Connection coherence (quality indicator)		
3.4.7 – Range	SAR image range pixel		
3.4.8 – Azimuth	SAR image azimuth pixel		
3.4.9 – Standard deviation	Standard deviation of average annual displacement rate due to uncompensated atmospheric error (mm/year)		
3.4.10 – PS point displacement	Displacement of each PS point relative to master image per scene		

3.5 – Processing summary report <i>Report includes:</i>			
3.5.1 – Process Date	mandatory		
3.5.2 – Software used	mandatory		
3.5.3 – Version	mandatory		
3.5.4 – Analysis type	mandatory		
3.5.5 – Number of scenes used	mandatory		
3.5.6 – Satellite data used	mandatory		
3.5.7 – Scale	mandatory		
3.5.8 – Georeference (X,Y) accuracy	mandatory		
3.5.9 – Reference data used for georeference	mandatory		
3.5.10 – Date range of analysis	mandatory		
3.5.11 – Date of master scene	mandatory		
3.5.12 – Projection system used	mandatory		
3.5.13 – Reference point location	mandatory		
3.5.14 – Perpendicular baselines and temporal separations of slave images relative to master(s)	mandatory		
3.5.15 – Coherence (or other) threshold applied	mandatory		
3.5.16 – Number of PS identified	mandatory		
3.5.17 – Area of results	mandatory		
3.5.18 – PS density (PS/km ²)	mandatory		
3.5.19 – PS motion statistics % of points in each mm/year class	Min to -3.5, -3.5 to -1.5, -1.5 to +1.5, +1.5 to +3.5, +3.5 to Max)		
3.5.20 – Displacement accuracy	mandatory		
3.5.21 – Standard deviation of average annual ground motion	mandatory		
3.5.22 – Spatial variation of above	mandatory		
3.5.23 – Observations	mandatory		
3.5.24 – Uncompensated atmospheric signal	mandatory		
3.5.25 – Over-compensated atmospheric signal	mandatory		
3.5.26 – Visible tilt or phase trends in motion map	mandatory		
3.5.27 – Are there any regions not covered by PS results? Location & reason	mandatory		

Table 15: Conformity to standard (End-User). This validates the technical conformity of the delivered product. The End-User is to provide a utility report describing the product validation in more detail.

Product type:	PSInSAR
Location:	Marseille/Gardanne, France
Filled out by:	N.O.Name, ESA (for this example, filled out by B. Kampes, DLR)
Date received:	July 9, 2005

Date returned: July 17, 2005 (v1); August 3, 2005 (v2, after product update by DLR)			
Protocol	Standard	Conformity	Comments e.g. tests applied, reason for non-conforming
1 – Product data layers			
1.1 – Reference multi-image reflectivity map (MIR) image	Standard deliverable		
1.1.1 – Projection	UTM, Datum: ETRS89 Ellipsoid: GRS80		utm zone:
1.1.2 – Data type	8-bit unsigned		
1.1.3 – Format	GeoTIFF		
1.1.4 – Georeference information	Integral GeoTIFF tags, Arc Info World file (.tfw) and text file of corner co-ordinates (.txg)		
1.1.5 – Colour table applied	Greyscale		
1.1.6 – Contrast stretch applied	Linear		
1.1.7 – Null value	255		
1.2 – Raster of interpolated average annual displacement rates	Standard deliverable		
1.2.1 – 32-bit floating point raster	Standard deliverable		
1.2.1.1 – Projection	UTM, Datum: ETRS89 Ellipsoid: GRS80		utm zone:
1.2.1.2 – Data type	32-bit float		
1.2.1.3 – Byte order	L-H (Little Endian, Intel)		
1.2.1.4 – Format	Simple array		
1.2.1.5 – Georeference information	Arc Info World file (.tfw), text file of corner co-ordinates (.txg) and ERMapper (.ers)		
1.2.1.6 – Null value	-9999		
1.2.2 – GeoTIFF raster	Standard deliverable		
1.2.2.1 – Projection	UTM, Datum: ETRS89 Ellipsoid: GRS80		utm zone:
1.2.2.2 – Data type	24-bit composite RGB		
1.2.2.3 – Byte order	N/A		
1.2.2.4 – Format	GeoTIFF		
1.2.2.5 – Georeference information	Integral GeoTIFF tags, Arc Info World file (.tfw) and text file of corner co-ordinates (.txg)		
1.2.2.6 – Colour table applied	Rainbow: Red-Orange-Yellow-Green-Cyan-Blue		
1.2.2.7 – Contrast stretch applied	Linear, min –5 mm/year, max +5 mm/year		
1.2.2.8 – Null value	255,255,255		
1.3 – Table of PS average annual displacement rate, include:	dBase IV (.DBF)		
1.3.1 – Code	PS unique identifier. The reference point is coded "REF".		
1.3.2 – Northing	UTM, Datum: ETRS89 Ellipsoid: GRS80		
1.3.3 – Easting	UTM, Datum: ETRS89 Ellipsoid: GRS80		

1.3.4 – Height	Retrieved PS height relative to reference point (m)		
1.3.5 – Displacement rate	Average annual displacement rate (mm/year)		
1.3.6 – Coherence	Connection coherence (quality indicator)		
1.3.7 – Range	SAR image range pixel		
1.3.8 – Azimuth	SAR image azimuth pixel		
1.3.9 – Standard deviation	Standard deviation of average annual displacement rate due to uncompensated atmospheric error (mm/year)		
1.4 – Table of PS time series	dBase IV (.DBF)		
1.4.1 – Code	PS unique identifier. The reference point is coded "REF".		
1.4.2 – Northing	UTM, Datum: ETRS89 Ellipsoid: GRS80		
1.4.3 – Easting	UTM, Datum: ETRS89 Ellipsoid: GRS80		
1.4.4 – Height	Retrieved PS height relative to reference point (m)		
1.4.5 – Displacement rate	Average annual displacement rate (mm/year)		
1.4.6 – Coherence	Connection coherence (quality indicator)		
1.4.7 – Range	SAR image range pixel		
1.4.8 – Azimuth	SAR image azimuth pixel		
1.4.9 – Standard deviation	Standard deviation of average annual displacement rate due to uncompensated atmospheric error (mm/year)		
1.4.10 – PS point displacement	Displacement of each PS point relative to master image per scene		
1.5 – Processing summary report <i>Report includes:</i>			
1.5.1 – Scale			
1.5.2 – Georeference (X,Y) accuracy	Value =		Seems better than 20 m.
1.5.3 – Reference data used for georeference	mandatory		
1.5.4 – Date range of analysis	mandatory		
1.5.5 – Projection system used	mandatory		
1.5.6 – Reference point location	mandatory		
1.5.7 – Number of PS identified	mandatory		

9.5 Example Service Validation Report

This section contains a complete example of a service validation report for a PSInSAR product. It is based on the processing performed by DLR for the PSIC4 study. Thus, DLR is the OSP, and the end-user is ESA. The processed area is near Marseille, France. The area of interest is North of Marseille, near the city of Gardanne, where significant subsidence occurs due to mining activities.

If the tables used in this example are different from the ones provided above, then the tables above are assumed to be most up-to-date and should be filled out.

SERVICE VALIDATION REPORT

Executive Summary

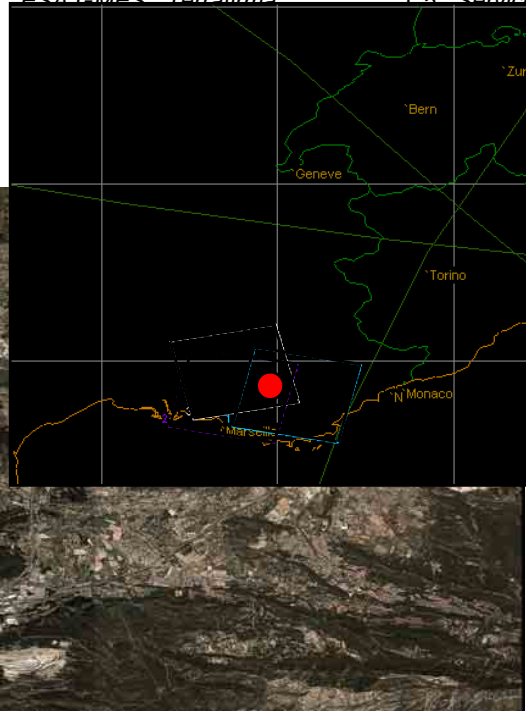
This summary provides the key elements of the service validation report, see Table 16. The end-user did not indicate a non-conformity of the delivered product. The key summary was sent to the Administrative Prime (the end-user had no objection.)

Table 16: Key summary (no entries have been removed upon request by the end-user).

1	Service Provider:	DLR
2	End-User:	ESA
3	Project Name:	Gardanne
4	Project Id.:	DLR/0211-0001
5	Start date:	December 1, 2004
6	Delivery date:	June 1, 2004
7	Service Provider:	DLR
8	End-User:	ESA
9	Area of interest:	Gardanne, France: 5.30E - 5.67E; 43.377N - 43.56N
10	Size of processed area:	40 km x 24 km
11	Expected deformation:	Mining induced, linear displacement model is adequate.
12	Type of processing:	PSInSAR
13	Number of different viewing geometries used:	1 track/frame, 1 viewing angle, 1 stack coherently combined
14	Number of images ordered per sensor, per viewing geometry:	ERS-1: XX ERS-2: XX
15	Number of images used per sensor, per viewing geometry:	ERS-1: XX ERS-2: XX
16	Ground-truth availability:	6 GCP; 2 stable areas; orthophoto
17	Non-conformities in product:	-none relevant-
18	Remarks OSP:	Successful estimation for this rural area. At some locations, some non-linear displacement is likely incorrectly estimated as atmospheric signal.
19	Remarks End-User:	-none-

1. Introduction

This service validation report describes the validation of the services provided by the *Terrafirma* service provider DLR to ESA, who requested a level 1 PSInSAR product for an area near Marseille, France, see Figure 4 for a brief overview of the processed area. This report is created to guarantee the reliable and consistent quality of delivered products, and their conformity to the agreed



standards regarding output format and accuracy, as defined in the *Terrafirma Service Portfolio Specifications* (dossier S5).

Standardized tables are used for this reason, which are provided in the following sections. The content of the tables are defined in the *Terrafirma Service Validation Protocol* (dossier C5), which scopes this report. The tables are filled out by the Service Provider (DLR), and by the End-User (ESA), see also section 2.

Ground-truth data is very important for the calibration of the PSInSAR product. It is also important to have information on the type of deformation. In this case, the end-user specified linear deformation to be likely.

Validation is performed on three levels. First, a check of technical conformity, then a check on relevance.

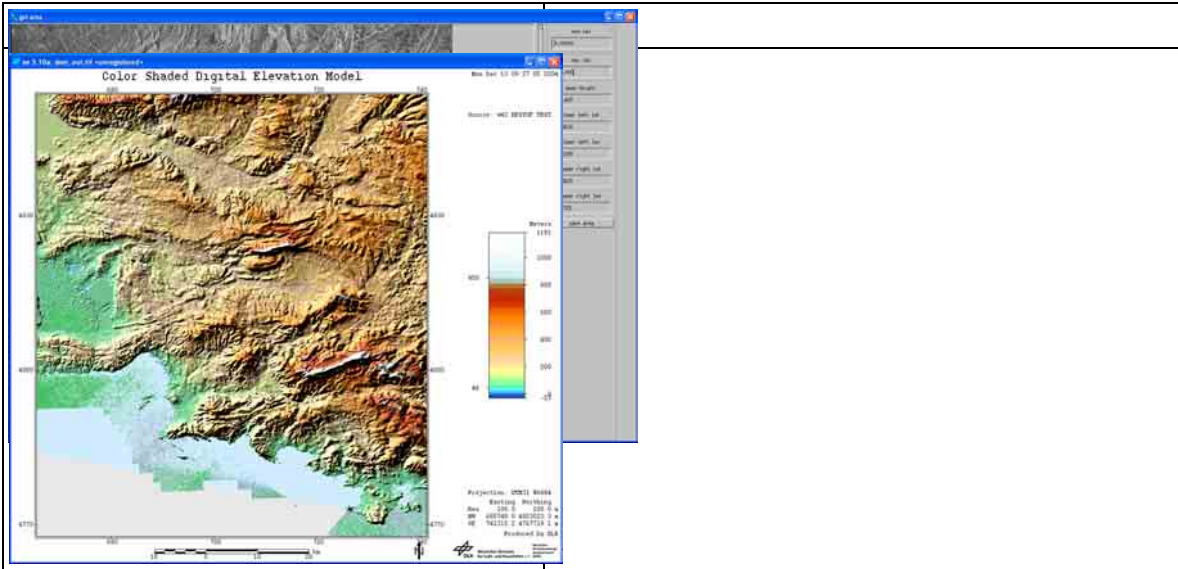


Figure 4: Data availability: upper left panel shows the coverage by ERS-1 and ERS-2 for the area of interest (red dot). Three stacks could be used: track 065 (106 acquisitions), track 294 (80 acquisitions, descending), and track 115 (32 acquisitions, ascending). The first stack was used. The plot on the right hand side shows an amplitude image and the proposed area to be processed. The aerial photo and DEM of the area shown on the bottom row were used to assess the probability of success of a PSInSAR processing before ordering.

2. STANDARD SERVICE VALIDATION TABLES

The following standard tables are defined in the *Terrafirma Service Validation Protocol* (dossier C5) and are included in each service validation report which always accompanies a Terrafirma product. These tables provide:

- Table 17: Overview of the necessary processing input data and validation of their conformity to the standards.
- Table 18: Overview of available input ground-truth data, available to the End-User for validation of the product, and the relevance during the processing and usage for calibration or cross-checking of the delivered product.

- Table 19: Validation of the service of ordering and delivery and conformity to the standards.
- Table 20: Overview and validation of the delivered level 1 PSInSAR product and conformity to the standards from the viewpoint of the Service Provider.
- Table 21: Overview of the PSInSAR product and conformity to the standards from the viewpoint of the End-User.

Table 17: Processing input data overview.

Product type: PSInSAR			
Location: Marseille/Gardanne, France			
Filled out by: B. Kampes, DLR			
Date: December 17, 2004			
Protocol	Standard	Conformity	Comments, e.g., tests applied, reason for non-conforming
1 – Satellite data set	ERS/ENVISAT/RADARSAT data. A list of the rejected acquisitions must be provided.	√	ERS data used. The processing report contains a table with the rejected acquisitions and reason.
2 – Topographic information resolution	Topographic map/DEM has a resolution of 3 arc second or better	√	SRTM-C, mixed with SRTM-X where available. Ellipsoid heights.
3 – Satellite state vectors (not obligatory)	Satellite state vectors obtained from Delft University, DLR, or CNES DORIS orbits, or other.	√	DLR
4 – Reference map/High resolution optical satellite data (not obligatory)	For georeference purposes. Output product georeference accuracy depends on the quality of the reference data and of the precision of the estimated height. Landsat ETM data is used by default unless higher quality data is available from the end-user.	√	High-resolution optical data provided by ESA. Additionally, 5 ground control points provided with aerial photos and GPS coordinates.
5 – Ground truth information (not obligatory)	Ground truth information regarding stable regions for reference point location is required to calibrate the displacement map.	√	Locations of two stable regions are provided.

Table 18: Validation input ground-truth data.

Product type: PSInSAR			
Location: Marseille/Gardanne, France			
Filled out by: N.O.Name (ESA); B. Kampes (DLR)			
Date: January 5, 2005			
Protocol	Standard	Relevancy	Correction decision

1 – layer data	Description: Orthophoto in GeoTIFF format. Source: ESA (unknown) Accuracy: 50 cm absolute position. Confidential: yes Provided to OSP at date: Jan. 5, 2005	√	[BK]: This data was used to check the georeferenced position of the computed PS points. The positions are not corrected using this data, because the ground control points are used for calibration of the timing, and no mismatch of the estimated position was found. [NN]: used to check the planimetry of the delivered product.
2 – point data	Description: 6 GCPs Source: GPS campaign (unknown) Accuracy: 3d position of the points within few meters. The locations of the points are indicated on aerial photos, and consist of the crossing of two highways, etc. Identification of the exact location of the GCP limits the precision to ~20m. Confidential: no Provided to OSP at date: Jan. 5, 2005	√	[BK]: The GCP is used to correct the range and azimuth timing of the sensor. The height of the reference point is estimated using the nearest 5 PS points to each GCP, under the assumption that the average height of these points should be equal to that of the GCP.
	Description: 2 stable areas. Source: ESA (unknown) Accuracy: 100 m absolute position Confidential: no Provided to OSP at date: Jan. 5, 2005	√	[BK]: Used to check whether the computed displacement field indeed is near zero in the stable areas. No correction performed.
	Description: levelling time series at 200 points. Source: ESA (unknown) Accuracy: 100 m absolute position Confidential: yes Provided to OSP at date: not provided	√	[NN]: used to compare the delivered time series in a blind experiment. Probably the OSP should have had access to this information during processing.

Table 19: Ordering/Delivery validation.

Product type:	PSInSAR		
Location:	Marseille/Gardanne, France		
Filled out by:	N.O.Name, ESA (for this example, filled out by B. Kampes, DLR)		
Date received:	July 9, 2005		
Date returned:	July 17, 2005		
Protocol	Standard	Conformity	Comments, e.g., tests applied, reason for non-conforming
1 – area of interest	Defined by end user: Gardanne, France	√	Processed area was larger than requested.
2 – period of interest	Defined by end user: 1992-2004	√	High-Doppler ERS2 data are not used. ENVISAT data are not used.
3 – delivery time	6 weeks after satellite data arrival.	✗	Special study; later delivery/six months project duration agreed between OSP and End-User.
4 – general comments on the ordering/delivery service		√	-none-

Table 20: Conformity to the product standards (OSP). This checklist is used to make sure that the delivered product conforms to the standards. The End-User is to perform product validation using all available ground-truth data.

Product type: PSInSAR Location: Marseille/Gardanne, France Filled out by: B. Kampes, DLR Date: July 17, 2005			
Protocol	Standard	Conformity	Comments, e.g., tests applied, reason for non-conforming
1 - Processing PSInSAR			
1.1 –Reference PS			
1.1.1 – Location	In stable area near displacement of interest	X	X= Y= height= Reference point is located in Marseille. It is a point with extremely good amplitude dispersion. This was regarded the best processing strategy.
1.1.2 – Calibration	Estimate bias in the estimated displacement rates using ground-truth and correct.	√	Correction applied = 0.0 (mm/yr); The estimated displacement rates in the stable areas are near zero, no additional correction applied.
1.2 – Atmospheric perturbations	Minimised within image using the (possibly temporally filtered) residual phase.	√	RMS Value = (mm/yr) not measured Atmospheric signal estimated by analysis of residual phase (Kriging) and removed.
1.3 – Platform position errors	OSP responsible for correction if deemed necessary	√	De-trending performed in range and azimuth.
2 - Resolution, accuracy, tolerances			
2.1 - Resolution			
2.1.1 –Pixel size during processing	nominal size	√	Pixels are oversampled to 10x2m;
2.1.2 – Displacement sampling	0.1mm/year	√	Delivered sampling is higher (floating point) but not conform standard.
2.2 – Accuracy			
2.2.1 – Absolute X, Y accuracy	15m	√	RMS value = (m) not measured; is within spec.
2.2.2 – Relative X, Y accuracy	+/-5m east/west +/-2m North/south	√	RMS value = (m) not measured; is within spec.
2.2.3 – Displacement precision	+/-0.1mm/year	√	RMS Value = (mm/yr) (provided by VAC)
2.2.4 – Displacement accuracy	General case	√	RMS value = (mm/yr) not measured; is within spec.
	Non-linear deformation	√	Agrees/does not agree (comparison with ground data points)
	Agreement with qualitative information	√	
2.3 – Tolerances			
2.3.1 – Number of images analysed	>20	√	Number = 69
2.3.2 – PS density	>/= 5 PS/km ²	√	Density value = 72

2.3.3 – Time series delivered	not for all estimated and delivered points a time series can be produced	√	Number = all.
2.3.3 – Time series location	Locations should agree with end user demand)	√	Density in area of interest is adequate; Time series delivered for each measured point.
3 – Product data layers			
3.1 – Reference multi-image reflectivity map (MIR) image			
3.1.1 – Projection	UTM, Datum: ETRS89 Ellipsoid: GRS80	√	utm zone: 33
3.1.2 – Data type	8-bit unsigned	√	
3.1.3 – Format	GeoTIFF	√	
3.1.4 – Georeference information	Integral GeoTIFF tags, Arc Info World file (.tfw) and text file of corner co-ordinates (.txg)	√	
3.1.5 – Colour table applied	Greyscale	√	
3.1.6 – Contrast stretch applied	Linear	√	
3.1.7 – Null value	255	√	
3.1.8 – Resolution	25 m x 25 m	√	
3.2 – Raster of interpolated average annual displacement rates			
3.2.1 – 32-bit floating point raster			
3.2.1.1 – Projection	UTM, Datum: ETRS89 Ellipsoid: GRS80	√	
3.2.1.2 – Data type	32-bit float	√	
3.2.1.3 – Byte order	L-H (Little Endian, Intel)	√	
3.2.1.4 – Format	Simple array	√	
3.2.1.5 – Georeference information	Arc Info World file (.tfw), text file of corner co-ordinates (.txg) and ERMapper (.ers)	√	
3.2.1.6 – Null value	-9999	√	
3.2.1.7 – Resolution	25 m x 25 m	√	
3.2.2 – GeoTIFF raster			
3.2.2.1 – Projection	UTM, Datum: ETRS89 Ellipsoid: GRS80	√	utm zone: 33
3.2.2.2 – Data type	24-bit composite RGB	√	
3.2.2.3 – Byte order	N/A	√	
3.2.2.4 – Format	GeoTIFF	√	
3.2.2.5 – Georeference information	Integral GeoTIFF tags, Arc Info World file (.tfw) and text file of corner co-ordinates (.txg)	√	
3.2.2.6 – Colour table applied	Rainbow: Red-Orange-Yellow-Green-Cyan-Blue	√	
3.2.2.7 – Contrast stretch applied	Linear, min -5 mm/year, max +5 mm/year	√	
3.2.2.8 – Null value	255,255,255	×	8 bit Geotiff delivered

3.2.2.9 – Resolution	25 m x 25 m	√	
3.3 – Table of PS average annual displacement rate <i>Table includes:</i>	dBase IV (.DBF)	✗	Comma separated value ASCII table is agreed with end-user
3.3.1 – Code	PS unique identifier. The reference point is coded "REF".	√	
3.3.2 – Northing	UTM, Datum: ETRS89 Ellipsoid: GRS80	√	
3.3.3 – Easting	UTM, Datum: ETRS89 Ellipsoid: GRS80	√	
3.3.4 – Height	Retrieved PS height relative to reference point (m)	√	
3.3.5 – Displacement rate	Average annual displacement rate (mm/year)	√	
3.3.6 – Coherence	Connection coherence (quality indicator)	√	
3.3.7 – Range	SAR image range pixel	√	
3.3.8 – Azimuth	SAR image azimuth pixel	√	
3.3.9 – Standard deviation	Standard deviation of average annual displacement rate due to uncompensated atmospheric error (mm/year)	√	Computed using estimated a posteriori variance factor.
3.4 – Table of PS time series <i>Table includes:</i>	dBase IV (.DBF)	✗	Comma separated value ASCII on request of end-user
3.4.1 – Code	PS unique identifier. The reference point is coded "REF".	✗	Code is 01233, because only number could be used in that column.
3.4.2 – Northing	UTM, Datum: ETRS89 Ellipsoid: GRS80	√	
3.4.3 – Easting	UTM, Datum: ETRS89 Ellipsoid: GRS80	√	
3.4.4 – Height	Retrieved PS height relative to reference point (m)	√	
3.4.5 – Displacement rate	Average annual displacement rate (mm/year)	√	
3.4.6 – Coherence	Connection coherence (quality indicator)	√	
3.4.7 – Range	SAR image range pixel	√	
3.4.8 – Azimuth	SAR image azimuth pixel	√	
3.4.9 – Standard deviation	Standard deviation of average annual displacement rate due to uncompensated atmospheric error (mm/year)	√	
3.4.10 – PS point displacement	Displacement of each PS point relative to master image per scene	√	
3.5 – Processing summary report <i>Report includes:</i>			
3.5.1 – Process Date	mandatory	√	
3.5.2 – Software used	mandatory	√	
3.5.3 – Version	mandatory	√	
3.5.4 – Analysis type	mandatory	√	
3.5.5 – Number of scenes used	mandatory	√	
3.5.6 – Satellite data used	mandatory	√	

3.5.7 – Scale	mandatory	√	
3.5.8 – Georeference (X,Y) accuracy	mandatory	√	
3.5.9 – Reference data used for georeference	mandatory	√	
3.5.10 – Date range of analysis	mandatory	√	
3.5.11 – Date of master scene	mandatory	√	
3.5.12 – Projection system used	mandatory	√	
3.5.13 – Reference point location	mandatory	√	
3.5.14 – Perpendicular baselines and temporal separations of slave images relative to master(s)	mandatory	√	
3.5.15 – Coherence (or other) threshold applied	mandatory	√	
3.5.16 – Number of PS identified	mandatory	√	
3.5.17 – Area of results	mandatory	√	
3.5.18 – PS density (PS/km ²)	mandatory	√	
3.5.19 – PS motion statistics % of points in each mm/year class	Min to -3.5, -3.5 to -1.5, -1.5 to +1.5, +1.5 to +3.5, +3.5 to Max)	√	
3.5.20 – Displacement accuracy	mandatory	√	
3.5.21 – Standard deviation of average annual ground motion	mandatory	√	
3.5.22 – Spatial variation of above	mandatory	√	
3.5.23 – Observations	mandatory	√	
3.5.24 – Uncompensated atmospheric signal	mandatory	√	
3.5.25 – Over-compensated atmospheric signal	mandatory	√	
3.5.26 – Visible tilt or phase trends in motion map	mandatory	√	none present
3.5.27 – Are there any regions not covered by PS results? Location & reason	mandatory	√	

Table 21: Conformity to standard (End-User). This validates the technical conformity of the delivered product. The End-User is to provide a utility report describing the product validation in more detail.

Product type: PSInSAR			
Location: Marseille/Gardanne, France			
Filled out by: N.O.Name, ESA (for this example, filled out by B. Kampes, DLR)			
Date received: July 9, 2005			
Date returned: July 17, 2005 (v1); August 3, 2005 (v2, after product update by DLR)			
Protocol	Standard	Conformity	Comments e.g. tests applied, reason for non-conforming
1 – Product data layers			
1.1 – Reference multi-image reflectivity map (MIR) image	Standard deliverable	√	Is delivered in dB, which is fine.

1.1.1 – Projection	UTM, Datum: ETRS89 Ellipsoid: GRS80	√	utm zone: 33
1.1.2 – Data type	8-bit unsigned	√	
1.1.3 – Format	GeoTIFF	√	Read in our GIS software without problems.
1.1.4 – Georeference information	Integral GeoTIFF tags, Arc Info World file (.tfw) and text file of corner co-ordinates (.txg)	√	
1.1.5 – Colour table applied	Greyscale	√	
1.1.6 – Contrast stretch applied	Linear	√	
1.1.7 – Null value	255	√	
1.2 – Raster of interpolated average annual displacement rates	Standard deliverable		
1.2.1 – 32-bit floating point raster	Standard deliverable	√	
1.2.1.1 – Projection	UTM, Datum: ETRS89 Ellipsoid: GRS80	√	utm zone: 33
1.2.1.2 – Data type	32-bit float	√	
1.2.1.3 – Byte order	L-H (Little Endian, Intel)	√	
1.2.1.4 – Format	Simple array	√	
1.2.1.5 – Georeference information	Arc Info World file (.tfw), text file of corner co-ordinates (.txg) and ERMapper (.ers)	√	
1.2.1.6 – Null value	-9999	√	
1.2.2 – GeoTIFF raster	Standard deliverable		
1.2.2.1 – Projection	UTM, Datum: ETRS89 Ellipsoid: GRS80	√	utm zone: 33
1.2.2.2 – Data type	24-bit composite RGB	√	
1.2.2.3 – Byte order	N/A	√	
1.2.2.4 – Format	GeoTIFF	√	
1.2.2.5 – Georeference information	Integral GeoTIFF tags, Arc Info World file (.tfw) and text file of corner co-ordinates (.txg)	√	
1.2.2.6 – Colour table applied	Rainbow: Red-Orange-Yellow-Green-Cyan-Blue	√	
1.2.2.7 – Contrast stretch applied	Linear, min –5 mm/year, max +5 mm/year	√	
1.2.2.8 – Null value	255,255,255	√	
1.3 – Table of PS average annual displacement rate, include:	dBase IV (.DBF)		
1.3.1 – Code	PS unique identifier. The reference point is coded "REF".	√	
1.3.2 – Northing	UTM, Datum: ETRS89 Ellipsoid: GRS80	√	
1.3.3 – Easting	UTM, Datum: ETRS89 Ellipsoid: GRS80	√	
1.3.4 – Height	Retrieved PS height relative to reference point (m)	√	
1.3.5 – Displacement rate	Average annual displacement rate (mm/year)	√	
1.3.6 – Coherence	Connection coherence (quality indicator)	√	
1.3.7 – Range	SAR image range pixel	√	

1.3.8 – Azimuth	SAR image azimuth pixel	√	
1.3.9 – Standard deviation	Standard deviation of average annual displacement rate due to uncompensated atmospheric error (mm/year)	√	
1.4 – Table of PS time series	dBase IV (.DBF)		
1.4.1 – Code	PS unique identifier. The reference point is coded "REF".	√	
1.4.2 – Northing	UTM, Datum: ETRS89 Ellipsoid: GRS80	√	
1.4.3 – Easting	UTM, Datum: ETRS89 Ellipsoid: GRS80	√	
1.4.4 – Height	Retrieved PS height relative to reference point (m)	√	
1.4.5 – Displacement rate	Average annual displacement rate (mm/year)	√	
1.4.6 – Coherence	Connection coherence (quality indicator)	√	
1.4.7 – Range	SAR image range pixel	√	
1.4.8 – Azimuth	SAR image azimuth pixel	√	
1.4.9 – Standard deviation	Standard deviation of average annual displacement rate due to uncompensated atmospheric error (mm/year)	√	
1.4.10 – PS point displacement	Displacement of each PS point relative to master image per scene	√	
1.5 – Processing summary report			
<i>Report includes:</i>			
1.5.1 – Scale		√	
1.5.2 – Georeference (X,Y) accuracy	Value =	√	Seems better than 20 m.
1.5.3 – Reference data used for georeference	mandatory	√	
1.5.4 – Date range of analysis	mandatory	√	
1.5.5 – Projection system used	mandatory	√	
1.5.6 – Reference point location	mandatory	√	
1.5.7 – Number of PS identified	mandatory	√	
1.5.8 – Area of results	mandatory	√	
1.5.9 – comments on the PS density (by Service Provider)	mandatory	N/A	
1.5.10 – PS motion statistics. % of points in each class	(Min to -3.5, -3.5 to -1.5, -1.5 to +1.5, +1.5 to +3.5, +3.5 to Max) mm/y.	√	
1.5.11 – Reference data for accuracy assessment	List:	√	
1.5.12 – Displacement accuracy	Value =	√	Checked with time series, see utility report.
1.5.13 – Standard deviation of average annual ground motion		√	
1.5.14 – Spatial variation of average annual ground motion	Value =	√	
1.5.15 – Observations	List:	√	

1.5.16 – Uncompensated atmospheric signal		√	
1.5.17 – Visible tilt or phase trends in motion map		√	
2 – Comments from End-User			
2.1 – Are there any regions not covered by PS results? Location & reason		N/A	
2.2 – General comment on the product	Is it conform your expectation, is it useful, etc.	N/A	
2.3 – Suggested changes to this table	Please specify	N/A	