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Validation Protocol for Emergency Response Geo-information Products

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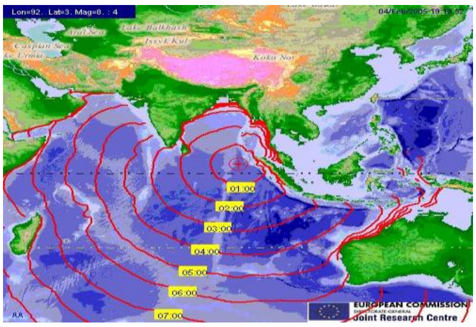

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1. INTRODUCTION

Europe is making a significant effort to develop (geo)information services for crisis management as part of the Global Monitoring for Environment and Security (GMES) programme. Recognising the importance of coordinated European response to crises and the potential contribution of GMES, the Commission launched a number of preparatory activities in coordination with relevant stakeholders for the establishment of an Emergency Response GMES Core Service (ERCS).
GMES Emergency Response Services will rely on information provided by advanced technical and operational capabilities making full use of space earth observation and supporting their integration with other sources of data and information. Data and information generated by these services can be used to enhance emergency preparedness and early reaction to foreseeable or imminent crises and disasters.

The portfolio of emergency services deals with:
1) Disasters - Natural risks: earthquakes and volcanic risk, floods, wild fires, tsunami, etc.
2) Disasters - Technological risks: major industrial accidents, hazardous materials spills due to natural disasters, major transport accidents: air, road and sea
3) Complex and compound emergencies: humanitarian consequences of conflicts

From a technical point of view, the use of geo-information for emergency response poses significant challenges for spatial data collection, data management, information extraction and communication. On one hand, the delivery of rapid and updated but nevertheless reliable products to end-users is considered a high-priority topic by users and providers; on the other hand, in crisis situations, the delivered geo-information is often ingested by the users without having the opportunity to review its quality and accuracy. Technical characteristics and constraints related to these new technologies may show complex interactions: for example the increase of spatial resolution of satellite sensor will lead to the decrease of spatial consistency of geo-databases generated using this sensor data. With the currently available reference data (GCP, DTM), panoramic and parallax distortion of the new generation satellite data generate a displacement error often greater than the pixel size in the final geo-information layers, with implicit effects on the quality of multi-temporal assessments and on the interoperability of the extracted geo-information. The introduction of high resolution SAR in flood mapping requires a careful assessment of its performance, especially in urban built-up, etc. The need for an independent formal assessment of these products to provide operational services at homogeneous and reliable standards has recently become recognized as an integral component of service development. The statement of “something better than nothing” is no longer valid. The need for robustness, quality and relevance of the information are gradually becoming recognized as a major component of satellite derived geo-products.

Validation is intended to help end-users decide how much to trust geo-information products (maps, spatial dataset) and, combined with quality assurance, can help to identify improvements.

The focus, in this document, will be on <u>geo-information products</u>, in particular those derived from Earth Observation data.

ERCS services addressing different thematic applications share a number of common characteristics:

i) they address similar operational needs;

ii) they produce similar outputs (e.g. reference maps, assessment maps, thematic maps);

iii) their outputs integrated into information environments that support decision making service.

This enables the definition of a common validation framework, the implementation of validation principles and the development of a validation process as a tool to check whether the products meet standards and user needs.

2. OBJECTIVES OF THE VALIDATION PROTOCOL

The validation principles, methods, rules and guidelines provided in this document aim to give a structure that guarantees an overall documented and continuous quality of ERCS services/products. The goal is to ensure that all products meet the required levels of accuracy, availability and affordability requested and expected by the end-users.

This validation protocol aims to define:

- Rules to ensure unbiased and independent validation;
- Top-level validation criteria, characteristics and parameters;
- The requirements for validation reference data sources

3. VALIDATION TERMINOLOGY

This chapter defines terms and some basic related concepts used in validation. These terms aim to distil a common terminology that can be used throughout GMES projects, especially in those activities that address validation (and quality assurance).

3.1. DATA, INFORMATION AND GEO-INFORMATION

- Data: is a raw signal recording, typically expressed as a numeric quantity. Data are registered by sensors (e.g. thermometer/temperature, gauges/water level, etc.). In ERCS, satellite sensors are a prime source of data, i.e. recordings of electromagnetic energy reflected/backscattered/emitted by the Earth's surface.
- Information: is data with a meaning, a semantic. Typical examples of information are the recording of all the damaged built-up structures in a given area, a population vulnerability index, a hurricane path, a flooded area.

  The distinction between data and information is only pragmatic. When the data collection is sufficient for our purpose, then the notion of data and information coincide. Information has always equal or greater abstract semantic level than the data, e.g. to know the amount (extension, volume) of surface water per spatial unit is data, to know where are the flooded areas (defining what we mean by that: how water height we need in order to classify it as flooded) is information.

- Geo-information: is information referred to a spatial context. If data and information coincide we can also talk about geo-data.
  Basic proprieties of geo-information are strictly related to: the reliability of the technique we use for collecting data (sensor, interview, other), the reliability of the method we use to semantically upscale data to information, the precision of the spatial reference.

3.2. PRODUCT, SERVICE, ATTRIBUTES AND PARAMETERS

ERCS deliver geo-information products for use in thematic applications within the emergency response realm. In the following some definitions of product validation related terms are presented.

- Product: is the delivered object containing geo-information. Examples are: a paper map, a digital map, a feature set accessible via a web service, etc.;
- Process: is the workflow to generate a product from input data, following a number of logical steps. For example, generating a fire map from input optical satellite sensor data is defined as a process;
- Service: is an implementation of a process put in place to generate a product and deliver it to the user;
- Provider: is an entity ("actor") that hosts a service. A provider may host one or more services. Furthermore, different providers may host a service that is similar in scope;
- Attributes of a product: a product has a set of attributes (characteristics) that determines the product as an acceptable service output. Some of these attributes can be described quantitatively, e.g. the positional accuracy and the thematic accuracy. Others can be described using qualitative parameters (e.g. readability).
- Attributes of a service: a service has a set of attributes (characteristics) that determine the service as acceptable process implementation. Some of these attributes can be described quantitatively, e.g. time to delivery. Others can only be described using qualitative parameters (e.g. quality of support).
- Parameters: are measurements to assess the attribute values. The parameters can be quantitative or qualitative. For example, to assess the "positional accuracy" attribute we can use the "Root Mean Square Error" parameter; to assess "readability", we can use "distinguishability of symbols" and "contrast between background and map themes" parameters.

3.3. VALIDATION

Validation can be defined as "a producer-independent process generating documented evidence to which degree the object subject to validation reaches predetermined requirements".
This synthetic definition deserves detailed comments:

- **Validation is producer-independent**: the aim of validation is to provide the (usually non-technical) user with a high level of assurance that the products meet standards and his needs, and should, therefore be producer-independent;
- **Validation is a process:** implies that a systematic reproducible approach (= a method) is defined to perform validation activities;

- **Documented evidence:** implies the definition of parameters, as much as possible quantitative parameters, i.e. metrics that can be reported and analyzed in order to assess the performance of a product/service;
- **Reaches predetermined requirements:** validation is not an "absolute" check. It is a relative check: it compares the object under validation to a reference level, in order to i) justify the cost of it (verification that the characteristics of the product/service acquired is as promised at the moment of the transaction), ii) minimize use problems (safety, misuse, etc.). This means that clear requirements covering all user needs are crucial for good validation practices. These requirements need to be as much quantitative as possible and to be defined prior to the conduction of validation activities. Whenever requirements are missing or are not sufficiently detailed, professional experience ("best practice") and expert knowledge shall be used. The predetermined requirements also imply that acceptable validity ranges and accepted tolerance are defined prior to the conduction of validation activities.

Validation is performed at the interface between the service provider and the end user. Both entities normally prefer that validation is performed by an entity that is independent from their interests. Validation requires in-depth knowledge of the service set-up, which may be commercially confidential. Therefore, a validating entity should have no commercial interest in similar service development. At the same time, the validation entity must have a good understanding of the intended end user service take-up, to ensure that product requirements have been sufficiently detailed to meet users' needs.

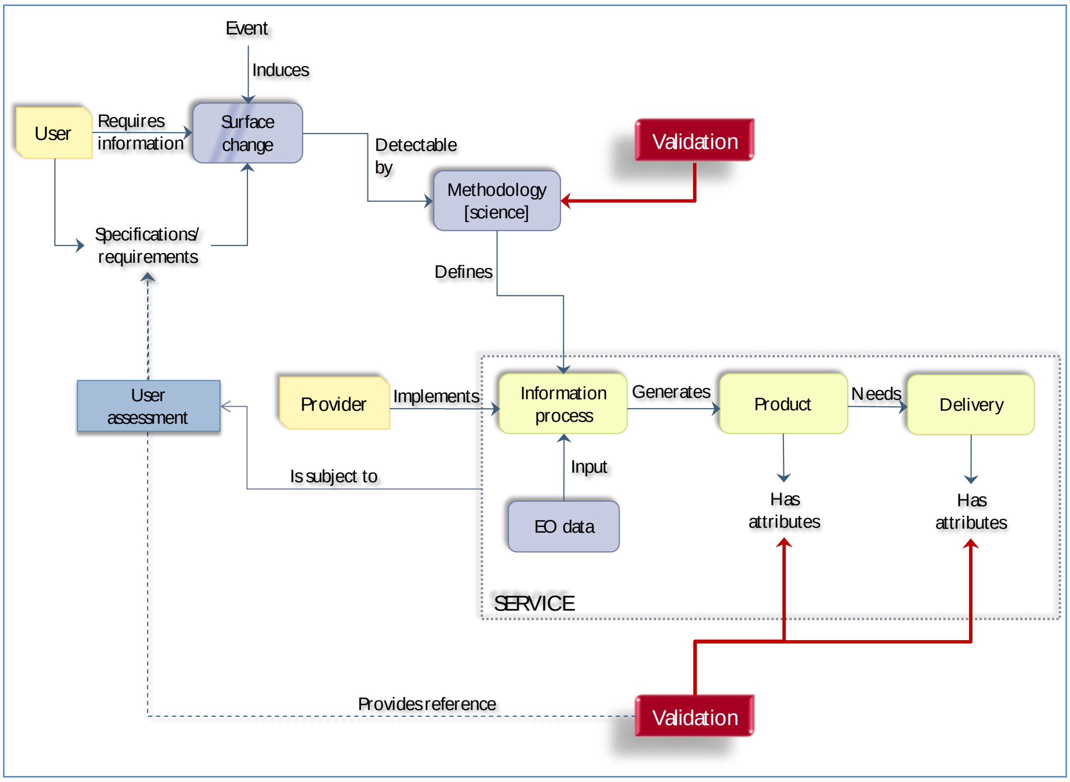

Figure 1. Logical diagram of ERCS and the role of validation

4. THE VALIDATION PROCESS

4.1. INFORMATION SOURCES FOR VALIDATION

Reliability of the information contents plays a major role in the validation process. To validate spatial and thematic accuracy or consistency, the general approach is to compare the product contents with other information sources, which can be classified in three main categories:

- Ground truth measures;
- Reference data sources;
- Other products containing similar information (inter comparison)

4.1.1. Comparison with ground truth data

Ground truth data regarding an emergency event are collected:

- at the location of the event;
- at event time or in a temporal range during which the situation object of interest doesn't change.

Ground truth sources are case dependant, e.g. ranging from ground control points collected in a field mission, to independent measurements of the event of interest (e.g. water level records in the case of floods, damage assessment reports (earthquakes), UNHCR field reports (refugee camps)).

This is the source that usually allows the best performances in terms of accuracy of the validation process and also usually demands most resources.

When ground truth data is required for validation, a proper collection strategy (on sampling basis) should be first developed, taking into account the financial and human resources required to undertake a substantive validation.

4.1.2. Comparison with reference data

When ground truth data is not available or is difficult to collect (e.g. due to disaster impact), comparison with independent reference data is needed to determine consistency.

Key to any consistency assessment is the provision of representative, independent reference data that is inherently more accurate than the product to be evaluated. For instance, when satellite data is used as a reference for validation, it should have a higher spatial resolution than the satellite data used to generate a product and/or better spectral and radiometric resolution.

Reference data should also encompass the same time period as the information product under validation.

According to the requirements of each product, the type and format as well as the spatial/ temporal criteria and thematic content of the reference data to be checked will be defined in section 4.6.

Typical reference data sources are VHR satellite images or airborne images. Increasingly, media reports are a source of event reference information.

Other specific reference data sources can be models, e.g. hydrological models for flood area estimation or physical vulnerability models for earthquake damages estimation. Of course, the application of a model introduces an additional step of uncertainty to the reference information extracted from the data source.

4.1.3. Product inter-comparison

Inter-comparison takes as inputs products coming from different service providers that have information contents similar to the contents of the product under validation. The products may also be based on independent data sources (e.g. a flood map derived from optical and SAR sensor data).
Inter-comparison only results in a measure of consistency between the compared products. Typical results include:

- the degree of difference between the product under validation and the reference;
- insights into the reasons of such differences and consequent identification of the possible weak points of the product.

The main advantage of such a validation is its relative low cost compared to a validation using reference data. It can be performed when access to reference data is difficult or too expensive or in special cases where a previously validated product is available and considered as suitable for validation purposes.

4.2. VALIDATION ON SAMPLE BASIS

Validation is expected to assess the characteristics of the products; in practice, with limited resources, it is not possible to fully validate all products for all services.
Thus, there is the need to define criteria to apply a multi-level sampling strategy: selection of priority services and products, space and time sampling.

Selection of priority services and products

The criteria to define priority services and products are:

- **user-criticality**: the services and products that involve the most serious emergency events or the ones which have the highest impact on user's workflow; errors in these have a high probability to cause losses;
- **frequency of use**: services and products most frequently used. An error in these has high probability to propagate;
- **novelty**: the new services and products, since they have not been exposed to operational constraints yet, known and trusted. Validation should be aimed at minimising the probability of erroneous use.

Spatial sampling

For a single product to be validated, design based surveys will be implemented. Sampling areas have to be defined and must fulfil the following general principles:

- **significance**: their dimension must be sufficient to ensure with high probability that the results are reliable;
- **representativeness**: their composition must include all relevant information the sampling is supposed to check.

Strata and clusters will be employed in thematic accuracy assessment. Strata are typically motivated by estimation objectives. For example, stratifying by map land cover class targets the objective of estimating class-specific accuracy, and stratifying by regions targets the

objective of estimating region-specific accuracy. Without stratification, the sample size representing a rare class or small region may be insufficient to precisely estimate accuracy. Budget and time constraints are two important inputs for defining the sampling design as they often limit the number of strata that can be effectively employed.
The choice of sampling areas is also driven by:

- importance of information to be validated;
- availability of information sources and cost of acquisition;
- advice from local experts for field mission, to define a detailed strategy optimizing the effort.

Temporal sampling
Also time sampling (repetition of sampling across different time instants) must follow general principles:

- Significance: the validation time interval must be sufficient to ensure with high probability that the results are reliable;
- Representativeness: the validation time interval must include information the sampling is supposed to check.

Practical criteria are:

- every kind of product delivered should be validated at least once
- validation should be conducted on a periodic basis to ensure the accuracy and the consistency of the geo-information
- the more often a product has been successfully validated, the higher will be its reliability and the lower the validation frequency needs to be.

4.3. EXERCISES: PAST AND LIVE EVENTS (FULL SCALE, REAL CONDITIONS)

Validation exercises should be performed both on past and live events. However, **priority should be given to live events**, mainly because they allow performing the validation of a certain product with the help and the full contribution of the users. Before implementing the validation, one should consider first the advantages and disadvantages of past and live events that may vary from one product to another:
For **live events**:

- The main advantages are: collection of quality reference ground truth data for validation; selection of representative products; they are more interesting to the users.
- The disadvantages are: some events occur more rarely than others (e.g. earthquake); need for and extensive time for preparation, expensive data collection.

For **past events:**

- The main advantages are: the ability to perform the validation for almost all kinds of events; the need for a short time frame to prepare and perform validation; in most case validation of past events is less expensive and easier.
- The disadvantages are: the data collected may not be of very good quality and the methodology used for data collection not well defined; the products may not be

completely representative of the different thematic and geographical areas of interest; they miss some important operational characteristics, especially on user involvement. Finally, there may already be some published works on the methodologies used or results produced by other service providers which could bias the validation set-up.

4.4. VALIDATION RANGES

For an efficient validation process, it is of utmost importance to specify not only the right validation parameters but also the validity ranges which imply acceptance or rejection. Ideally, validation is resulting in a cross-check for each validation parameter. The more stringent the allowed validity ranges, the more likely a product or service may fail to meet the requirements. It is not always essential to validate every parameter, but it is necessary to define a ranking for each kind of service.
Some pertinent questions may help in defining the validity ranges:

- What precision and accuracy is required for the essential information layer?
- How robust should the product be?
- How fast should the process and product information delivery be?
- What is the minimum required performance?

Furthermore, service improvements that are integrated into ERCS should typically lead to a narrowing of validity ranges, to reflect that the service indeed performs at a higher level. In general the purpose of the validation expert is to evaluate the Map as a whole, but in emergency cases maps must be produced in a very short time, so it is possible that the provider must strike a balance between rapidity and accuracy. That's why it is important to consider this matter in the validation procedure evaluating first of all if the map is useful for its peculiar purpose, focusing the attention on the most crucial aspects.
A weight should be given to each validation parameter to give more importance to what is crucial for the user. There cannot be a unique reference scale of ranges for every kind of map: the priorities should be defined for most of cases by the users, or, if it is not possible, by the expert of validation, according to the users' needs. Usually the priority should be given to the major information about the emergency that the Map is supposed to give: for example if the map regards flood, the detection of flood is the most important. But the analysis can go deeper inside the problem: if the major problem regards people involved, the flood detection on urban areas is particularly critical, in other cases the attention could be focused on the impact on agriculture, and so on...
The main criteria should be:

- To point out which is more important between thematic and positional accuracy
- Considering thematic accuracy, to point out which layers are more sensitive

Then for each parameter different levels of acceptability should be defined (the validation ranges). Different statistical approaches are needed for the determination of validation ranges. In principle, validation is performed for a representative sample of services. This sample should reflect different types of events and it should represent significantly the total volume of mapping unit produced. Depending on the thematic information, sampling may be non-uniform, but rather skewed to represent most significant areas of interest (e.g. for flood maps, high value areas may be sampled at higher rates that low value areas).

Validation ranges help to formally rank the products and services and allow the identification of particular problems that should be addressed by the service provider in order to improve a certain product or service set-up. Users benefit from validation results through the enhanced trust in products or reliance on services that successfully pass validation and the gradual improvement in service evolution. The role of the users in defining ranges is crucial: the purpose of the ranges is not theoretical, but it aims to allow the validation being really user driven.

4.5. THE VALIDATION MODEL AND ITS CRITERIA

In this sectionthe framework for the validation protocol is defined. Validation relies on a set of quantitative as well as qualitative parameters that can be grouped into four categories.

1) Reliability of the information content
2) Consistency of the information support
3) Usability of the product
4) Efficiency of the service

Each category requires a specific set of validation parameters, validation tools and methods. The validation methodologies will be further developed in the following.

4.5.1. Reliability of the information contents

Reliability is generally defined as the degree to which the **information contained in a product** is similar to a reference (also called "ground truth"), dependable or repeatable (stability), i.e. the degree to which it is free of errors, logical and complete. Reliability regards also the soundness of the methodology and of the sources used to generate the product.

Most of the GMES ERCS are implementations of methods that require Earth Observation data as inputs. For instance, the flood mapping service can be based on the detection of radiometric changes that are due to the change of the physical properties of the observed surface from the normal state (i.e. not flooded) to a flooded state. The reliability of the radiometric change detection depends on the characteristics of the remote sensing sensor (spatial, spectral and temporal resolution, technical characteristics of the registration and processing) and environmental conditions at the time of image acquisition (e.g. atmospheric conditions, surface characteristics, seasonal effects). The process to transform the data in radiometric measurements into information about flood extent involves various technical processing steps (e.g. geo-referencing, radiometric calibration) and decision steps that lead to the delineation and presentation of the "flooded area" class. This process may differ across services (i.e. process implementations) because methods and tools to perform technical processing may vary, decision criteria for class delineation are applied differently, or the presentation formats differ. These differences may even exist for different service classes, implemented by the same service provider. For instance, a "rapid" service instance may include technical processing steps that are optimized for speed, rather than technical accuracy, leading to a different output than a "slow", and more precise, variant of the same service. Interestingly, this suggests that a "flood mapping" service requires further specification, as in "rapid flood mapping with medium resolution SAR", or "precise flood mapping with VHR optical data", as these produce rather different outputs, and each may require a specific validation context.

In summary, Earth Observation data provide indirect measurement of the state that is of thematic interest in a specific Respond service (e.g. a flood map, an actual refugee camp overview). These indirect measurements may suffer from:

- **Insufficient spatial resolution**, i.e. the sensor produces imagery at a resolution that is not sufficient to resolve the detail needed for the thematic output. For instance, individual buildings may not be sufficiently detailed in a 5 m image product to allow accurate damage assessment;
- **Insufficient radiometric resolution**, i.e. the sensor sensitivity to radiometric changes is not sufficient to resolve different objects or different states that are of interest to the observed process. Alternatively, the process under observation may not result in sufficient radiometric diversity to allow resolution of different states in the sensor output. For example, it may not be possible to differentiate between flooding depth if the sensor's radiometric channels saturate at a certain depth;
- **Insufficient temporal resolution,** i.e. the sensor's revisit frequency is too low to capture the relevant stages of the dynamic event. This may either be due to technical limitation due to orbit configuration or versatility of the steering capability or environmental conditions (e.g. cloud cover). For instance, the imagery may not have captured flooding at its maximum extent;
- **Heterogeneity**: the quality of the image inputs may vary by sensor (e.g. due to difference in radiometric or geometrical resolution) but also for the same sensor for different areas and/or epochs, due to variation in viewing configuration, atmospheric conditions, seasonal changes, etc. Especially in the rapid mapping case, where input data may need to be selected on a first come, first serve basis, this can lead to considerable heterogeneity in map output quality;
- **Class dependencies, non-linearity, incompleteness**: interpretation of the remote sensing images typically depends on model assumptions that are specific to a class (e.g. land use classes), within a limited validity range. Such model assumptions may even be specific to a certain geographical area (e.g. there is no universal model for an urbanised area). Non-linear effects (e.g. saturation) may limit the applicability of the model assumption. Incompleteness may limit the effective coverage of the mapped area (e.g. limited by sensor field of view) or the class delineation (essential bands missing);
- **Subjectivity**: service outputs are some form of image interpretation, which may be based on subjective decisions (e.g. threshold definition, class assignment, grouping criteria). Subjectivity contributes to in-service and between-service variability.

Availability of pre-event reference data is generally critical depending on the instrument and geographical area. Archives for commercial imagery are generally sparse for areas outside commercially or strategically important areas. Reference maps may come from a range of sources, with different scales, quality, age, thematic content, etc., especially in areas of the world where no uniform mapping standards exist.

The reliability of the **information source,** i.e. the sensor data**,** is one of the first criteria defining the reliability of the derived product. Because of the entropy theorem in the information theory, the reliability and overall quality and usefulness of the final product can only decrease starting from the reliability of the information sources. The minimization of this entropic degradation is, of course, the objective of the **quality control** design and management.

Measuring or assessing reliability implicitly assumes that reliability of a product is the same for all users. It is based on very careful analysis of the product and most of the time it requires independent reference data.
Validation of the information content reliability for products includes:
- Checking the thematic accuracy (against ground measurement) and consistency (against other reference data) of the information content of the product;
- Check the positional accuracy (against ground control point) and consistency (against georeferenced reference data) of the information content of the product;
- Check the temporal adequacy of the information contained in the product;
- Check spatial representation of the mapped theme with respect to the event's spatial extent;
- Check completeness of the information content of the product;
- Define a sampling framework for on-site ground truth collection, if required;
- Ensure the independence of the source from political and economical interests;
- Derive event specific criteria for ranking of permissible errors (quality statement).
The complete list and the definition of the parametric tests belonging to this category are given in section 4.6.1.

4.5.2. Consistency of the information support

This category of validation parameters addresses the quality of the cartographic support or of the geospatial infrastructure that contains the geo-information. It takes into account not only the absolute quality of a certain information layer or feature but also the relative consistency between the different information layers or features contained in a specific product (e.g. the relative positional consistency across different feature sets in the same product). It deals with the representation of the information from the thematic, positional, geometrical and temporal point of views.
Validation of the consistency of information support includes:
- Assessing the **internal logical consistency** of the cartographic support or of the geospatial infrastructure. Internal consistency is related to i) the interrelations among cartographic features themselves (e.g. compatibility between the geographic projections of the different entities or geo-information layers included in the same product) and ii) cartographic features and their attributes (e.g. domain consistency);
- Checking the consistency between spatial detail and absolute positional accuracy;
- Checking the geometric quality (e.g. ensuring the compliance with topological rules) and completeness of the information support;
- Ensuring the respect of generalization rules which is based on i) the selection of an appropriate scale given the map purpose and the map audience and ii) on the set of processes used to manipulate the spatial information such as the following well-known generalization operators: simplification, smoothing, refinement, etc.
- Checking the temporal consistency among the different features, i.e. determining the age of different data layers included in the product;
The complete list of validation characteristics belonging to this category is detailed in the validation protocol. They were derived from basic cartographic rules and are of utmost importance for the communication of the information to the user.

4.5.3. Usability of the product

The usability of a product is contingent upon its appropriate use; that is through avoidance of misuse or erroneous use. It is directly related to the communication of the geo-information to others. This issue centres on the following question:

Will the users find the geo-information product useful and informative?

Using a geo-information product includes reading, interpreting, analysing and eventually integrating the information contained in the product. Therefore, it is crucial to eliminate any misunderstanding and ambiguities. Ensuring the usability and avoiding the problems of misunderstanding and misuse of a product require a collaborative approach between the user and the producer.

From the validation expert’s standpoint, checking the usability of the product is one of the most crucial aspects of the validation. A particular stress will hence be given to this category since most of the defined parameters are directly derived from user requirements and expectations. In that sense, validating the usability aims at narrowing the gap between the service provider and the end user.

Some of the validation characteristics belonging to this category will certainly vary depending on the intended audience, technical limitations and specific requirements. However, we can generally identify 5 main groups of parameters:

1) **Media used**: the data exchange format used for delivering a certain product to the end user will depend on the specific use context and is not generalizable to all classes of geo-information products (e.g. a map printed on water-proof media for use in tropical area during the rainy season is a typical need linked to a specific use context).
2) **Readability**: refers not only to the visual perception of information contained in a product but also to cognition, which deals with the users thought processes, prior experiences and memory. The principles of cognition are important because they explain why certain symbols work (i.e. communicate information effectively). To illustrate the importance of cognition, we may take the examples of the use of different colours (e.g. blue or red) for representing the flood extent in different map products. For a certain user, accustomed to see flooded areas in blue, the presence of the red colour representing flood extent will be confusing since it might be associated with burned areas seen on a previous map.
3) **Metadata consistency**: the presence of metadata is essential not only for electronic based geo-information (e.g. GIS data) but also for paper maps. Validation of metadata consistency concentrates on the conformity to a compulsory set of standard metadata fields (e.g. conform to ISO 19115).
4) **Access and sharing restrictions**: clear statements on the constraints to access, use, information sharing and copyrights are important for evaluating the extent of the usability of a certain product. These may either be part of the agreed metadata standard, or documented separately beforehand (e.g. for a class of products).

4.5.4. Efficiency of the service

The discussion in this section is relevant in the context of validation, as it provides a critical review of the overall service provision. The understanding of inherent quality issues and dependencies is relevant in the design of targeted validation techniques that test the validity constraints for a given process, under a given set of circumstances (event).

Whereas heterogeneity in the input data affects product quality, can service delivery be affected by the operational supply of the input Earth observation data? This is particularly relevant for the “rapid” service implementations for post-event mapping. For a comparative analysis of the affected area, the best possible resolution imagery is generally preferred as closely timed to the event date as possible, both for the pre-event reference and post-event situation assessment. Post-event image acquisition requires an elaborate analysis of programmable resources. Furthermore, delivery time of satellite data depends both on technical parameters, such as geographical location, which determines both acquisition planning and the need for onboard recording, as well as commercial (e.g. conflicting priority or exclusivity) and even political issues (shutter control, restricted access). The latter is particularly important in crisis situation with a political dimension, and typically for very high resolution data (e.g. sub-meter resolution optical and SAR systems).

Dependency on third party processing tools may exist as well, for instance, image processing software that contain different geometrical or radiometric correction routines. This is particularly relevant if the complexity of the information content extraction requires application of sophisticated, and time consuming, algorithms, analysis of time series and multi-sensor data sets.

Finally, effective delivery of the service outputs may depend on the access to enabling technologies such as high-bandwidth Internet, tele-communication means, enhanced computing environments, etc., both at the service producer and service user end. Formats and standards are relatively well established, especially for standard reporting (e.g. PDF, web-mapping), but end-user service uptake may require further integration into the electronic workflow within the end-user organisation, especially if this extends to local users in remote areas.

The three previous categories of criteria (reliability of information content, consistency of information support, usability of the product) refer to validation characteristics that are relevant to a product or a group of products delivered by a service. Efficiency of the service is related to the infrastructure delivering the product(s). Ensuring the efficiency of the service is as important as validating the individual products. However evaluation of efficiency will be strongly dependent on the type of service: archive, proactive, reactive, alerts.

The efficiency of a service includes the **performance**, the **availability**, the **affordability** and the **integrity**.

Performance is about timing. The time it takes the system to respond to an event generally provide the basic measure of performance. The service performance indicators will be based on the performance criteria such as:

- List of events and delivering time from the order or response time performance
- Volume of service delivered (number of maps, …)
- Support services delivered (training, …)
- Quality control results
- Multilingual call centre option available
- Multi-layer (internet, phone, video conference) platform available

The key question that should be addressed when evaluating the performance of a service is:

What is the added value of the information derived from service use when compared to information derived from other sources (e.g. media reports, internal information sources)? Can improvements (if any) be quantified?
Availability is related to system failure and associated consequences and is characterized by the probability of the system being operational and readily accessible when the user needs it. It also checks if 24/7 option is available.
Affordability is related to the cost of the service, the general rule being that overall benefits should normally justify the overall cost. One major issue that should be addressed here is:
Does service delivery and integration lead to additional costs (e.g. extra work, need for hardware/software)?
Integrity is the extent to which geo-information product is delivered correctly by the service without any alteration in the delivery process (aspects of handling, distribution and information delivery or access). This assumes that the validation expert traces the service output as soon as it is produced at the provider's unit and checks against the delivered product once it reaches the end-user. Checking the integrity means also to look at the media or the system used to deliver the product and assess its compliance to standards and its adequacy for the type of information it is supposed to supply.

4.6. ANALYTICAL DESCRIPTION OF ATTRIBUTES TO BE VALIDATED

In the following, the four main categories of attributes: reliability of the information content, consistency of the information support, usability of the product and for efficiency of the service, are listed and described with the concerning attributes to be validated. For each validation category, it will be:

i) first, recalled the definition;
ii) then explained the different attributes and give some indications on the metrics that will be used for assessing these attributes;
iii) then given guidelines on the methodologies that can be used to estimate these parameters. The detailed methodologies will be provided in future versions of the validation protocol;

4.6.1. Reliability of the information content

Reliability is generally defined as the degree to which the **information contained in a product** is similar to a reference (also called "ground truth"), dependable or repeatable (stability), i.e. the degree to which it is free of errors, logical and complete.From the user point of view, reliability is a statement about how much the user is confident in the map given its purpose. This is not a mathematical definition like accuracy or uncertainty, but is a judgment made by the map-user and may therefore depending on the purpose of the map. However, this judgment can be supported by evidence from:

-Accuracy measures

-Evaluation of all contributing data

-Independent validation

-Expert opinion

-User support: Generally found to be acceptable by stakeholders and the map has stood the test of time

In the following the products' attributes are presented, they will be examined during the assessment of the reliability. Also the parameters (measurements) that can be used for evaluating the quality of these attributes will be listed. The methods that can be implemented for collecting and analyzing these measurements will be detailed in the next version of this protocol.

1]Thematic accuracy (based on in-situ data)

Accuracy in general is the degree to which a measured value conforms to a true or accepted value. Accuracy is a measure of correctness. It is distinguished from precision, which measures exactness.
In an image classification or in a map in general, a variety of errors can be encountered. Typically, interest focuses on thematic accuracy, which is the correspondence between the class label assigned by the classification and that observed in reality. The latter refers here to ground-observed data. In thematic accuracy, there are two elements: the correct *class* at the correct *location.* In other words, have the data at point X been correctly classified?

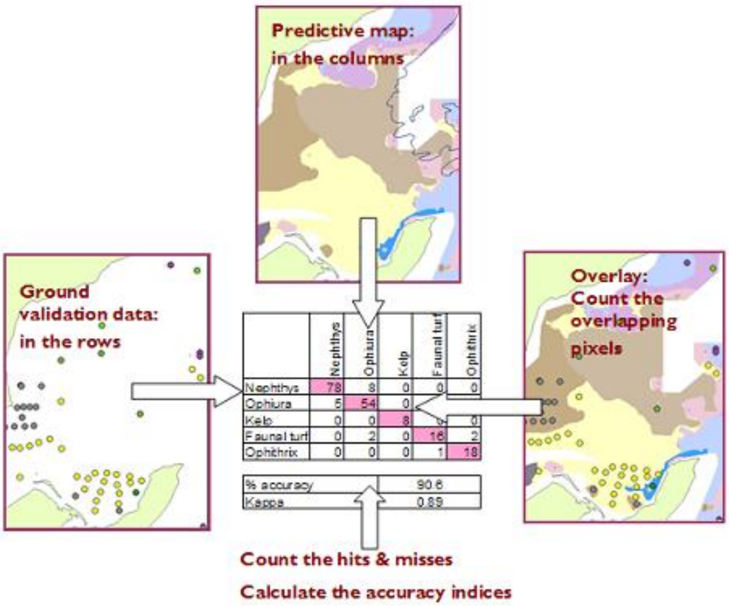

Figure 2- Principle of accuracy assessment using ground-truth data

A map or a geo database can be constituted of several information layers or features. The thematic accuracy can hence vary from one feature to another in the same geo-information product. It is therefore necessary to classify the different layers according to their importance for the user and relatively to the main event that is being mapped. This classification can then allow to perform a prioritized thematic accuracy assessment and to concentrate the effort on the most meaningful features.

❖ ***Parameters/methods used for measuring thematic accuracy:***

Thematic accuracy can be assessed using quantitative parameters. The most widely used measure of accuracy is the confusion matrix despite the large number of accuracy assessment metrics described in remote sensing literature.

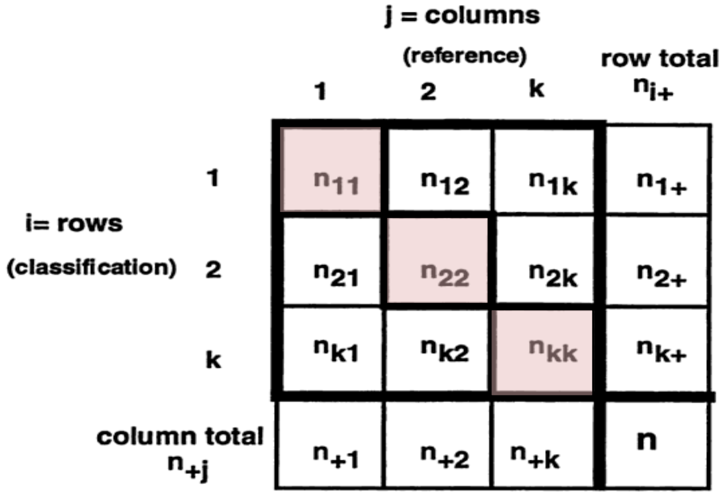

Figure 3 - The confusion matrix and some common measures of classification accuracy that may be derived from it.

Figure 3 shows the confusion matrix and some common measures of classification accuracy that may be derived from it. The highlighted elements represent the main diagonal of the matrix that contains the cases where the class labels depicted in the image classification and ground data set agree, whereas the off-diagonal elements contain those cases where there is a disagreement in the labels. In the example shown, the number of classes, q, is 3. (Foody, 2002)

The **confusion matrix** is as a simple cross-tabulation of the mapped class label against that observed in the ground or reference data for a sample of cases at specified locations, it provides an obvious foundation for accuracy assessment (Campbell 1996; Canters 1997). Indeed, the confusion matrix provides the basis on which to both describe classification accuracy and characterize errors. Alternatively, the **pattern of misclassification** evident in the matrix may aid studies that use the map, particularly as a means to estimating the areal extent of classes over a region.

The confusion matrix can be obtained by overlaying ground reference data (ground validation sample data) over the map. Many measures of classification accuracy or accuracy indices can be derived from the confusion matrix:

- *Overall accuracy* = $\frac{\sum_{k=1}^{q} n_{kk}}{\;} \times 100$
- *Producer's accuracy* = $\frac{n_{ii}}{n_{+i}}$
- *User's accuracy* = $\frac{n_{ii}}{n_{i+}}$
- *Kappa coefficient* $= \frac{n \sum_{k=1}^{q} n_{kk} - \sum_{k=1}^{q} n_{k+} n_{+k}}{n^2 - \sum_{k=1}^{q} n_{k+} n_{+k}}$
- *Thematic errors*: two types of thematic error, *omission* and *commission*, are possible and both may be readily derived from a confusion matrix (Congalton and Green 1993). An error of omission occurs when a case belonging to a class is not allocated to that class by the classification. Such a case has been erroneously allocated to another class, which suffers an error of commission.

In addition to these common accuracy measures, it is proposed also to calculate other complementary measures:

- *Conditional Kappa*= $\frac{nn_{kk} - n_{k+}n_{+k}}{nn_{k+} - n_{k+}n_{+k}}$

This coefficient looks at the agreement for an individual class within the matrix.

2]Thematic consistency (based on consistency check with other sources, excluding in-situ data)

The difference between thematic accuracy and thematic consistency lies in the reference data used for the validation. While thematic accuracy uses ground-observed (*in-situ*) data, thematic consistency is based on other types of reference data that do not require any field work. A reference satellite imagery, a topographic map or even inter comparison with another product can be used for performing a consistency check of thematic information when *in-situ* data are not available.

❖ ***Parameters/methods used for measuring thematic consistency:***

Quantitative and qualitative parameters can be used for checking the thematic consistency.

a) Quantitative measures: as for thematic accuracy measures, the confusion matrix can also be used for assessing the thematic consistency. It must, however, be recognized that in the absence of in-situ data, the resulting confusion matrix and accuracy statement may be significantly distorted by errors in the reference data. It is therefore necessary to establish a protocol for the collection of reference data that applies an index of confidence to the reference data so that different subsets can be evaluated, or to use secondary class labels to allow a softer evaluation of the degree of agreement between the data sets to be calculated (Zhang and Foody 1998). A further problem arises as a consequence of the sampling strategy adopted for the collection of ground/reference data. The protocol for the collection of ground/reference data will have also to define the sampling design that will be used depending on the scale and of the units mapped in the geo-information product (e.g. pixels or parcels).

b) Qualitative measures: Although a statistically rigorous assessment predicated on a probability sampling design is still the “gold standard” for assessing the thematic consistency, other approaches that are less costly can add significantly to the understanding of errors and the potential improvement of the map’s consistency. One of these is systematic quality control, which consists of a quick, qualitative survey that is performed over every part of the map. This systematic assessment of the quality of the maps increases the quality of the final products and is recommended as a preliminary step prior to implementing the more formal consistency assessment. Qualitative validation is based on a systematic descriptive protocol, in which each cell of the map is visually examined and its consistency documented in terms of type of **cell composition**. This qualitative assessment can be translated in the form of quantitative metrics of the landscape complexity and of spatial pattern within each examined cell. This protocol proposes to use the following indexes: **fragmentation index**, **heterogeneity index** and **Shannon entropy index**.

3] The absolute positional accuracy of the information

The absolute positional accuracy is a measure of discrepancy between the position of the features represented on the map or in a geo-information layer and their real position obtained from ground surveys. To allow validation, ground surveys must produce data quality better than product data quality.

The concept of absolute positional accuracy is equivalent to the concept of scale. For paper maps it refers to the *cartographic* scale (representation scale), since the accuracy of information contained in the map is determined by representation scale. For digital geo-datasets (vectors and rasters), it refers to the *nominal* scale (scale of data acquisition), since visualization is physically possible at any scale but the accuracy of information contained in the dataset is determined by the scale of data acquisition.

Positional accuracy combines two concepts: precision and location. Precision is the spatial detail:

- for raster products, it is the resolution;
- for vector products, it is lied to the instruments and techniques used to produce the data;

4] The relative positional consistency of the information

Relative positional consistency is the measure of the average discrepancy in distances between the positions of the features represented on the map and their positions obtained from reference data such as satellite imagery, a topographic map or national geo-database. It is the same concept as absolute positional accuracy, the only difference lies in the use of reference data that is not ground survey and then cannot be strictly considered as ground truth. Nevertheless, to allow validation, reference data must have better quality than the product's quality.

❖ ***Parameters/methods used for measuring the absolute positional accuracy and the relative positional consistency:***

The **Root Mean Square Error** (RMSE) will be used to estimate the positional accuracy and the **relative RMSE** will be used for measuring the relative positional consistency.

RMSE is the square root of the average of the set of squared distances between dataset coordinate values and their true values obtained from ground-truth surveys. The **relative RMSE** is based on the same equation, but, in this case, the reference coordinate values are obtained by an independent source of higher accuracy (e.g. a larger scale map, a georeferenced remote sensing image with finer resolution).

Accuracy is reported in ground distances at the 95% confidence level. Accuracy reported at the 95% confidence level means that 95% of the positions in the dataset will have an error with respect to true ground position that is equal to or smaller than the reported accuracy value. The reported accuracy value reflects all uncertainties, including those introduced by geodetic control coordinates, compilation, and final computation of ground coordinate values in the product.

Class 1 Planimetric Accuracy Limiting RMSE (meters)	Map Scale
0.0125	1:50
0.025	1:100
0.050	1:200
0.125	1:500
0.25	1:1,000
0.50	1:2,000
1.00	1:4,000
1.25	1:5,000
2.50	1:10,000
5.00	1:20,000

Table 1- ASPRS Accuracy Standards for Large-Scale Maps

One major issue is the number and the distribution of Ground Control Points (GCPs) and check points. Normally, for large scale maps, a minimum number of 20 check points should be tested; distributed to reflect the geographic area of interest and the distribution of error in the dataset. When 20 points are tested, then the 95 percent confidence level allows 1 point to fail the threshold given in product requirements.

Table 1 shows the planimetric accuracy standards (class 1, horizontal) according to the American Society for Photogrammetry and Remote Sensing (ASPRS (1990) for large scale maps. The values in this table are based on the cartographic convention to fix the minimum readable thickness for graphics elements of a map. This thickness is usually set in the interval 0.2 - 0.3 mm (0.25 in Table 1).

5] Time gap

The closer the time between the event and the source of mapped information, the more reliable the map is to the user. Therefore the time gap is an important attribute of the products delivered. Since a dataset or map can contain several themes obtained at different dates, it will be important to rank these themes according to their importance to the users and to search out the time gap between the event of interest and the most important themes.

- ***Parameters/methods used for determining the time gap:***

The time gap can expressed in hours, days, months or even years. This information can be obtained either from metadata or directly on the map. It can also be checked by comparing the declared dates to catalogues of satellite imagery or to other independent sources of temporal information.

6] Information on occlusion (clouds, artefacts) expressed as a percentage of the spatial extent and

7] Information on occlusion in the form of a mask representing occluded areas

Determination of unmarked areas due to artefacts or clouds is essential for the user to better understand the information content. This information can express in the form of a percentage of the spatial extent of the mapped area and/or directly represented on the map (i.e. occluded areas represented with a mask and defined in the legend).

❖ ***Parameters/methods used for checking information on occlusions:***

This information must be declared either in the metadata or directly on the map (in the interpretation text, or in the form of a mask). Therefore the parameter that will be used for assessing this attribute is the **presence/absence** dichotomy with values corresponding to 1 (for presence) and 0 (for absence).

8] Overlap between geo information layers

Maps will often contain objects and areas that overlap (e.g. lines representing streams might run over lines that represent roads, and both sets of lines may be drawn over areas). Sorting and arranging information in separate layers and then drawing them in an order that reduces ambiguities on the final display plays an important role in the final reliability of information content. When overlapping areas occur in the same layer, it is possible to encounter confusing effects.

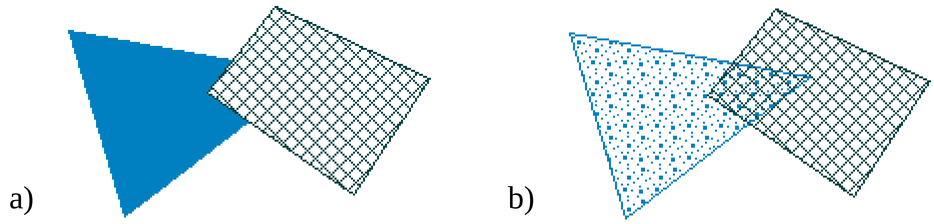

Figure 4- a) Ambiguous and b) non ambiguous overlapping.

Figure 4 illustrates ambiguous and non ambiguous overlapping situations:

a) Ambiguous situation where one cannot tell if, the area formatted using a crosshatch style and a white colour for background, is simply drawn as overlapping blue triangle or if it's perfectly into a regular shaped blue area;

b) Non ambiguous situation where two overlapping areas are formatted in two different drawing layers using a slightly contrasting colour and a slightly different open pattern style.

❖ ***Parameters/methods used for determining overlap:***

Absence of overlap is encouraged; therefore the **presence/absence** parameter will be used for this attribute. However, sometimes it is impossible to avoid overlapping and consequently simple cartographic rules and common sense can help to represent the information in an unambiguous way. For that, the **pertinence** parameter will also be used allowing to rank the representation of overlap into five categories: Very Bad, Bad, Fair, Good and Very Good.

Figure 5- Examples of overlay between geo information layers

These two subsets were taken from a map representing damaged building and infrastructure. The yellow line represents the cadastral limits, the red and yellow dots represent the damaged buildings and the red cross is for the damaged airport (runway sections). On the first subset, we can observe an overlay between the cadastral limits and the damaged buildings. On the second one, there is an overlay between the toponyms, the damages airport and the cadastral limits. The parameter used to assess the overlay in this case is the “pertinence”. In this case, were the most important information is the location of damage; the order of the layers is not pertinent, because it does not respect the levels of relative importance of geo information. This overlay does not only affect the reliability of information content but also the readability of the map.

This is another example showing an overlap between the most important geoinformation layers. Mainly we can identify an overlap between urban areas, represented in blue and the envelop of burnt areas represented with a red line. The latter also includes information on land cover, mainly dense (represented in dark green) and sparse vegetation (represented in light green). The use of transparent texture could have been preferable.

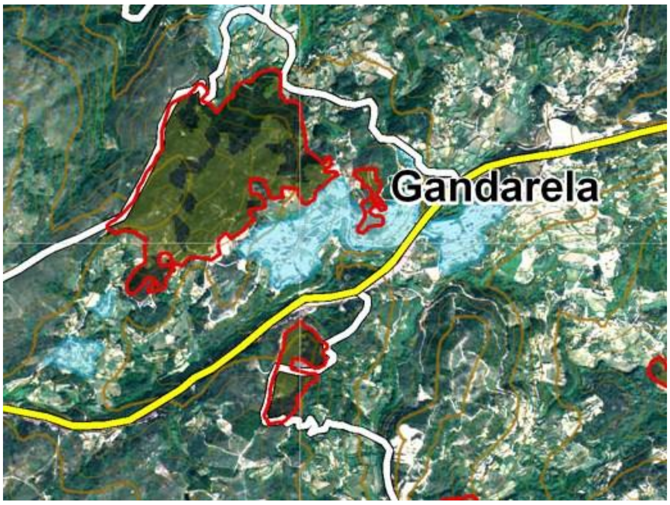

Figure 6- Example of overlay between urban areas, represented in blue and the envelop of burnt areas represented with a red line and including as well an information on land cover, mainly dense (dark green) and sparse vegetation (light green).

9] Semantic definition of information content (either public or ad hoc)

Every feature represented on a map should normally be defined in a comprehensible form. This can be done in the legend, which is a kind of dictionary that provides a key for understanding the different symbols used on a map. It is desirable to mention the source of the definitions used in the legend (whenever the features description is based on a commonly used legend e.g. Corine landcover) for an increased reliability of information content.

- ***Parameters/methods used for assessing the semantic definition of information content:***

In addition to the **presence/absence** of semantic definitions of information content on the map, the **completeness** of the definition will also be used as a quality parameter. In other words, this parameter allows to check if all the symbols are defined in the legend and if a reference on the source of definitions is available.

10] Information on the spatial detail of information sources

The spatial detail (precision) of information refers to the granularity of the data that is used for generating the product. Information on the spatial detail is essential to check the consistency of the spatial accuracy of the product.

- ***Parameter/method used for checking the information on the spatial detail of the information source:***

The **presence/absence** check is used in the documentation of information on the spatial resolution for raster data (image data) and on the nominal scale for vector data.

11] The methodology used for accuracy assessment

In some cases, the service providers give indications on the spatial/positional accuracy of the delivered product. In that case, it is essential to know what is the methodology (sample size, type of reference data, sampling design, accuracy metrics, etc.) used for determining the accuracy of the delivered product.

- ***Parameter/method used for checking the information on the methodology used for accuracy assessment:***

Besides the **presence/absence** of information in the documentation of information on the methodology used for accuracy assessment, the **pertinence** or suitability of the methodology will also be examined. The latter depends on: i) the quality of the reference data used for accuracy assessment, ii) the sampling density, iii) the sampling scheme, etc.

12] Credibility

Credibility of the service provider is one of the main aspects that determine the reliability of the information contained in a geo-information product. Evaluating the credibility or believability will help the users in establishing trust in the service and in the products it delivers.

- ***Parameter/method used for assessing the credibility:***

A **documentation of the scientific reputation and of the operational experience** of the service provider will be established as a measure of credibility. Besides the **independence** (yes/no) of the source from political/economical interest is also a criteria that can help in assessing the credibility of the service provider. This can be performed based on the validation expert's experience, on the experience record and the reputation of the source and on validation results.

4.6.2. Consistency of the information support

A consistent product is the one that does not contain contradictions. While reliability of information contents is mainly based on comparison with reference sources, consistency checks focus on internal contradictions of the product, between different components of the product (documentation included) or with respect to requirements.
When a contradiction between two or more elements is detected, it is seldom possible to decide which the correct one is, but the presence of a contradiction is a good hint that the product contains errors, and then further investigation is worth.
Consistency validation requires as input the product (documentation included) and the requirements, no reference source is required for most part of the checks.
Different parameters and methods apply depending on the information support (i.e. the media, the format) used for the product.
Consistency validation offers the following advantages:

- It does not require reference sources (for most part of the checks);
- It can be run time-independently from data sources acquisition;
- It is less expensive with respect to validation of reliability of information contents;
- For digital products, a relevant part of consistency validation can be automatic or computer assisted, thus it can be performed automatically on the full product (not only on sample basis as compared to reliability of information content).

For these reasons, consistency validation is sometimes used as a relatively fast and un-expensive 'pre' validation.

1] Consistency between absolute positional accuracies (spatial details)

This attribute describes consistency between spatial attributes of the product. Starting from the information sources and ending at the final product, the information quality can only eventually decrease because of processing. Then, if a product has a declared positional accuracy, this implies that the information contents (features/image) must have at least the same minimum positional accuracy. Also the information sources must have the same minimum positional accuracy.
In other words, a product with spatial accuracy of 2.5 meters (scale1:10000) must really allow to read 2.5 meters spatial information and have information sources with spatial accuracy of 2.5 meters or better.

❖ ***Parameter/method used for checking the consistency between spatial detail and absolute positional accuracy***

The first parameter is the ratio between declared absolute positional accuracy of the product and declared absolute positional accuracy of information sources. This is a trivial check. The values should be contained into the documentation.
The second parameter is the ratio between declared absolute positional accuracy of the product and absolute positional accuracy of information contained in the product. The challenging part regards the estimation of positional accuracy of information contained in the product. It is often easier to estimate its spatial detail and use it instead of accuracy to obtain a bound.

For all products (in particular paper products), it is possible to try an estimation of spatial consistency with known elements contained in other themes.

For digital products, computer assisted or visual examination are possible, for paper, a detailed visual examination can sometimes give a rough estimate.

2] Relative positional consistency across different feature sets in the same product

This attribute describes consistency between spatial information contained in the product. There are features with expected positional relation between themselves, e.g. (partial) adjacency of municipality/county/state boundaries, containment of bridges in transport networks. In addition to this, many thematic features can also be easily observed on very high resolution satellite imagery or an aerial photograph e.g. transportation networks, water bodies. If the product contains features/images with these relations, it is possible to evaluate their relative positional consistency. The following figures show some examples of inconsistencies.

Figure 7 – Probable inconsistency between boundaries (dashed) and the background image

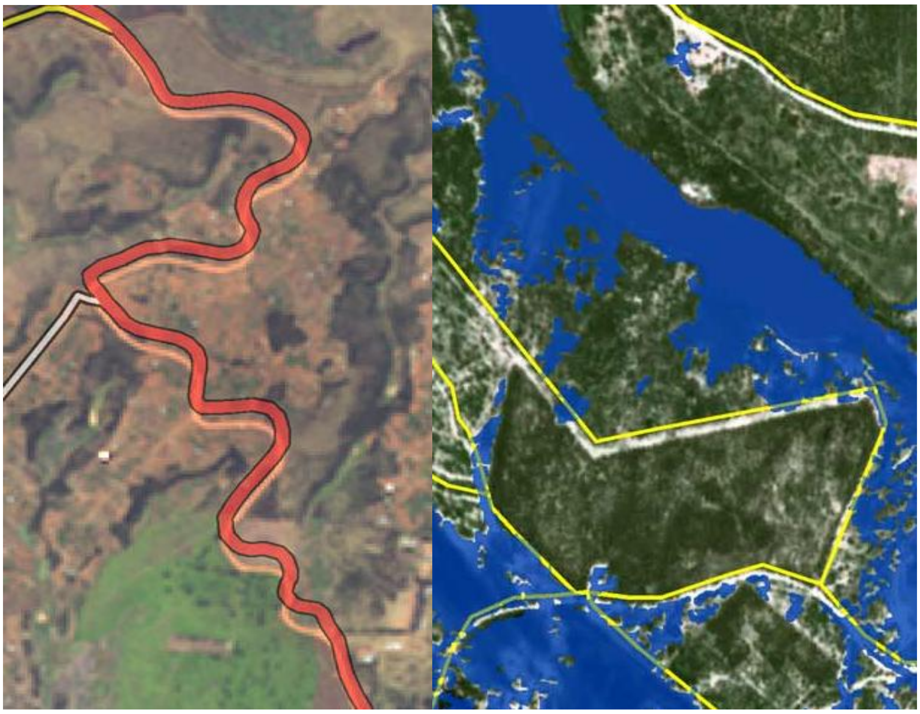

Figure 8 – Inconsistency between roads in thematic features and roads in the underlying image

❖ ***Parameter/method used for checking the consistency across different feature sets in the same product***

The main parameter is RMSE. It can be calculated with different methods depending on the type of product (paper map, digital map, …):

- Paper maps: RMSE will be compared to the cartographic scale. It is also possible to compute RMSE using measures in mm taken directly from the map and to compare this RMSE with the graphical accepted tolerance (0.2 – 0.3 mm). A visual inspection of the map usually allows a quick assessment of major problems.
- Digital maps (images, not georeferenced data): the default approach is to visualize or print at the proper cartographic scale and to use the same procedure applied to paper maps.
- Georeferenced data: in this case computer aided assessment is the best approach to compute RMSE. The resulting value has to be compared with the nominal scale.

3] Relative time gap between most significant features

This attribute describes the time distance between the most significant features included in the product.
The interpretation of this attribute is case dependant. There seem to be no general rule; a loose reference could be that the features should refer to the same date (as close as possible to the event of interest). Knowledge of time gap helps in identifying and explaining the artefacts (i.e. identifying discrepancy related to newly built up information).

❖ ***Parameter/method used for checking the relative time gap between most significant features***

Time measures: hours, days, months, years between data features. This information can be checked in metadata.

4] Respect of generalization rules

Generalization is the process of reducing the information content of maps due to scale change, map purpose, intended audience, and/or technical constraints. For instance, when reducing a map from large scale to small scale, some of the geographical features must be either eliminated or modified because the amount of map space is significantly reduced. Of course, all maps are to some degree generalizations, as it is impossible to represent all features from the real world on a map, no matter what the scale (Slocum, McMaster et al. 2005).
Examples are: representation of cities from metric (polygon) to symbolic (point), representation of green or built areas without some internal (minor) roads, even if the cartographic scale will allow to represent them.
Generalization can be performed using many spatial operators, described in the following figure.

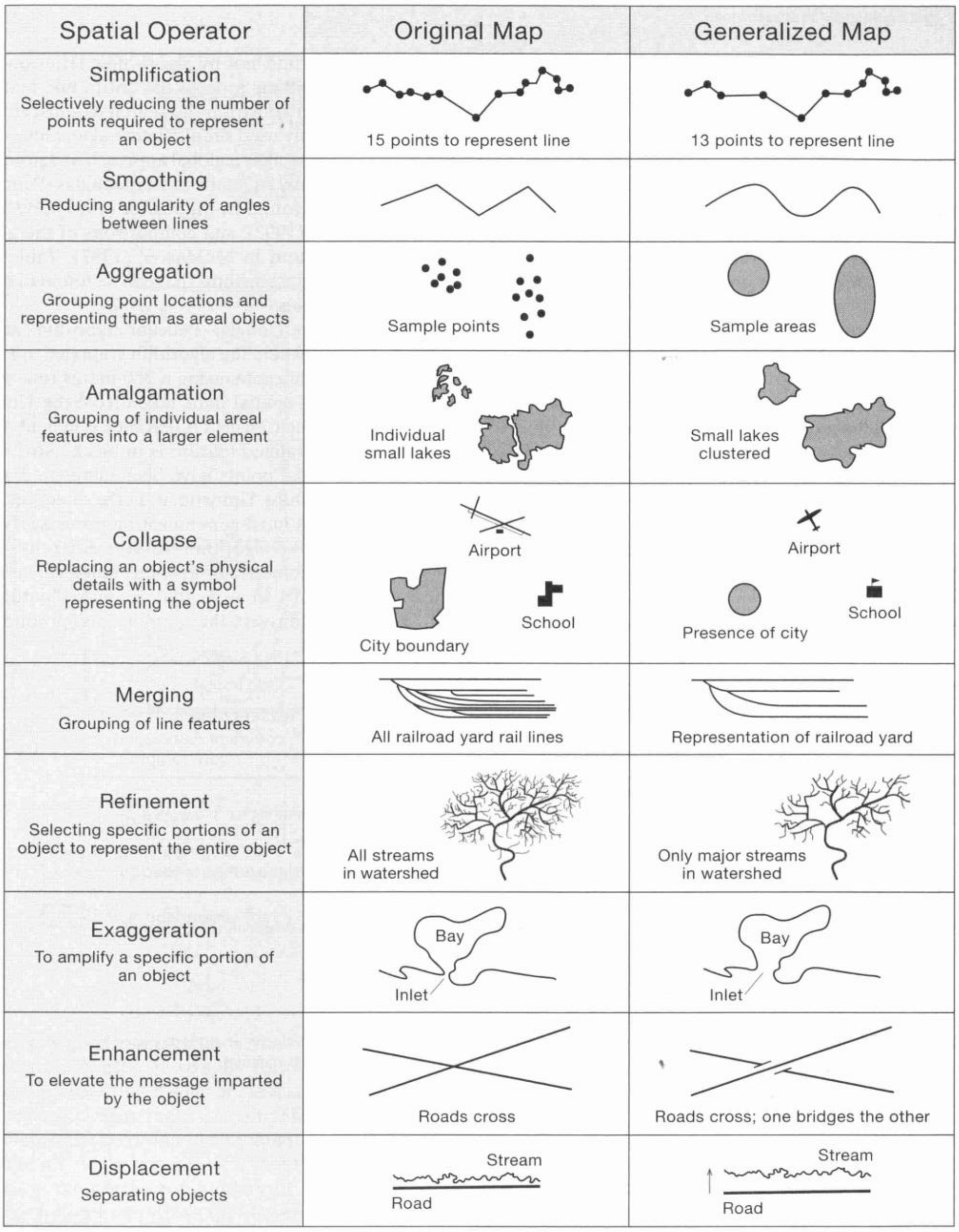

Figure 9 – Spatial operators for generalization (Slocum, 2005).

❖ ***Parameter/method used for checking the respect of generalization rules***

It is not possible to perform a complete and a systematic check; it is proposed to focus on: pertinence of symbolic representation and pertinence of metric representation according to different scales and semantic hierarchy.
The method is to understand which generalization process has been used by checking in metadata and have a visual examination of the map.

5] Consistency between map and legend symbols

The map and the legend must contain a consistent set of symbols:
- all symbols used in the map must be named in the legend;

- all symbols named in the legend must be used in the map. If the map is divided into tiles, it may occur that not all the symbols represented in the legend are visible on all the maps.

The following figures show some examples of inconsistencies.

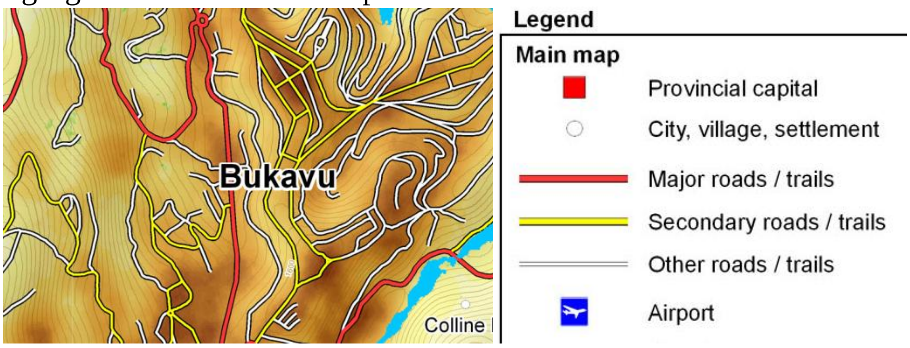

Figure 10 – the legend symbol for provincial capital is missing in the map

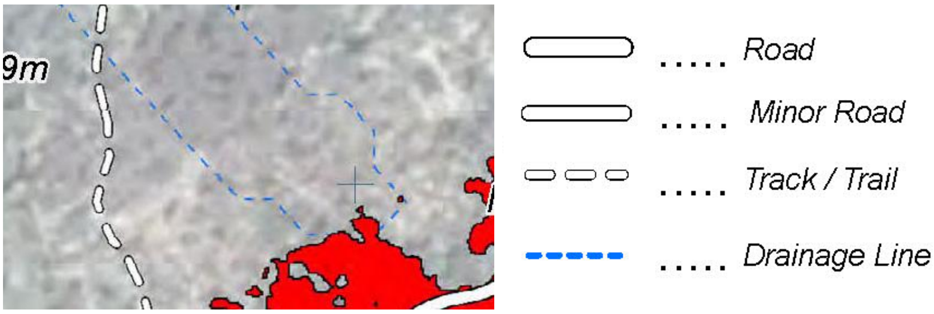

Figure 11 – The symbol for drainage line has different sizes in the map and in the legend

❖ ***Parameter/method used for checking the consistency between map and legend symbols***

The parameters used to evaluate consistency between map and legend symbols are:

- the percentage of symbols present in the map and described in the legend
- the degree of graphical correspondence between those symbols.

The method to assess these parameters consists in a visual check on the map.

6] Compatibility between the geographic coordinate/projections systems

A single product can contain different features (or geo-information layers) coming from different sources. If the features are stored in different coordinate/projection systems, this can cause consistency problems as displacement or deformation of the information.

If the product is a map, two main cases exist:

- the inconsistency is managed during the production process, using coordinate transform and re-projection tools
- the inconsistency propagates to the product; in this case it is usually detected performing ‘relative positional consistency across different feature sets’ check.

Any transformation applied to data that affects the coordinates or the reference system should appear explicitly in the metadata and also its effects on the map precision should be mentioned.

If the product is a dataset, there is the need to perform a systematic check.

- ***Parameter/method used for checking the Compatibility between the geographic coordinate/projections systems***

The main parameter is the pertinence of the coordinate/projection systems. It can be evaluated checking metadata, checking properties of geographic data files and by visual inspection.

7] Topological consistency

Topology studies spatial properties that are preserved when an object is deformed in a continuous way, i.e. stretched without either tearing or gluing. Topological consistency is achieved when the required properties are respected in the product.
The importance of topological consistency lies in the fact that it increases the effective usability of data: every geo-data can be printed, but the area can be calculated only for *closed* polygons and the minimum path can be calculated only for *connected* networks. Thus, the respect of topological properties can be very important for specific geo-information products, depending on their expected use.
In addition to this, topological relations can help to detect content errors, e.g. a dam should be contained in the boundary of water bodies

- ***Parameter/method used for checking topological consistency***

There are several parameters to describe topological consistency. Some examples are:

- adjacency: some features could be constrained to be adjacent, e.g. administrative boundaries, roads sections that separate cities and the administrative boundaries;
- cover/inclusion: some features could be constrained to be completely covered by /included in others, e.g. the polygon of state surface should include the polygon of each city of that state. Of course the type of inclusion depends on the geometric feature types: linear represented dams should be contained in the boundaries of polygonal represented water bodies; punctual represented dams should be contained in linear represented water bodies;
- presence of gaps: gaps in a feature dataset could be allowed or not, e.g., a land use cover should have no gaps;
- overlapping: overlapping between features of the same or of a different dataset could be allowed or not; (digitizing happens to produce overlapping in the same feature);
- closure of polygons: polygons should be closed in order to properly allow some operations as area calculation, inclusion check. The case of not closed polygons can occur when geometry is digitized using CAD tools;
- connection of networks: for some linear features, the connection property could be required, e.g. for transportation network when path processing is necessary;
- presence of dangles: a line with an endpoint that is not connected to another line is called a dangle; this could be allowed or not;
- continuity (across tiles): features should not have unwanted breaks that reduce usability. For instance, big datasets are often processed partitioning the study area into tiles and digitizing features into each single tile. This practice can lead to features (roads, coastline, …) that are not continuous across the tiles.

There are many computer aided tools to help checking topological parameters in datasets. The availability of such tools enables to perform extensive systematic checks on the complete product.
Visual analysis is suitable for maps.

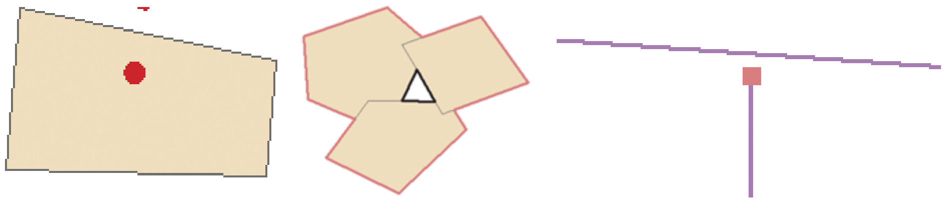

Figure 12 – Inclusion (of a point in a polygon), presence of a gap, dangle line (ESRI)

Figure 13- Example of topological inconsistency

These are subsets of two reference maps representing road infrastructure, delivered by the same service provider. The red circles highlight a topological inconsistency observed between the two maps. The parameter used to assess the topological consistency is the "Continuity of geographical features". Thanks to a simple visual comparison of the two maps, it is possible to identify breaks in the geographical features (here the roads) in the map represented on the left. This may be a source of confusion for users who receive these two maps, which are supposed to represent the same information at the same scale.

8] Attributes consistency

Geo-data has alphanumeric attributes and they are also an important source of information. Attribute consistency refers to data types and values that attribute can have. This property is also known as domain consistency (Bernhardsen 1999).
The importance of attribute consistency lies in the fact that it increases the effective usability of data, e.g., every data can be printed, but only *numerical* data can be used for numerical computing (not numbers written in character fields). Thus, the respect of attribute consistency can be very important for specific geo-information products, depending on their expected use.
In addition to this, attribute consistency checking can help to detect content errors, e.g. an absolute speed cannot be negative.

❖ ***Parameter/method used for checking attribute consistency***

There are several parameters to describe attribute consistency. Some examples are:

- data type compliance: the data types contained in the product must be compliant with the expected data types, e.g. number, character, date,…;
- value range: the attribute values must be included into expected (or anyway reasonable) ranges, e.g. surface mountain height could be expected to be in the range [500m – 9000m], EU language in the list [bg, cs, da, de, et, el, en, es, fr, ga, it, lv, lt, hu, mt, nl, pl, pt, ro, sk, sl, fi, sv]
- filling of required fields: some fields could be required for further computing and they must be filled.

There are many computer aided tools to help checking attribute consistency in datasets. The availability of such tools enables to perform extensive systematic checks on the complete product.
Visual analysis is suitable for those attributes that have explicit output on maps, e.g. classifications (this check is usually performed under thematic accuracy/consistency activities).

9]Consistency between declared and effective representation scale

The effective representation scale of the product could be different from the declared representation scale. If the product is meant for metric use, i.e. to assess distances, it is worth to check this consistency. This check applies only to maps that are meant to be printed. The representation scale can be declared in different ways, the most used are a proportional scale bar, e.g. 

and a numerical ratio, e.g. 1:100,000.

❖ ***Parameter/method used for checking consistency between declared and effective representation scale***

If the scale bar is used, the check consists in defining control points on the paper/digital map, measuring their map distance, getting the real metric distance by a reference source, and comparing these data with the scale bar.
If the ratio is used, with paper maps, the check consists in defining control points on the map, measuring their map distance, getting the real metric distance by a reference source, and comparing these data with the ratio.
If the ratio is used, with digital maps, the same check is possible only if information on physical dimension of paper sheet is given. Performing this check will also define if the declared physical dimension is consistent.

4.6.3. Usability of the product

The usability of a product is contingent upon its appropriate use; that is through avoidance of misuse or erroneous use. It is directly related to the communication of the geo-information to others. This issue centres on the following question:

Will the users find the geo-information product useful and informative?

Using a geo-information product includes reading, interpreting, analysing and eventually integrating the information contained in the product. Therefore, it is crucial to eliminate any misunderstanding and ambiguities. Ensuring the usability and avoiding the problems of

misunderstanding and misuse of a product require a collaborative approach between the user and the producer.
From the validation expert's standpoint, checking the usability of the product is one crucial aspect of the validation. A particular stress will hence be given to this category since most of the defined parameters are directly derived from user requirements and expectations. In that sense, validating the usability aims at narrowing the gap between the service provider and the end user.

1] Spatial coverage of the area of interest

The location and the extent of the area represented on a map is the first thing that must be examined at the delivery of a product. A map that does not cover the area of interest is not useful to the end user. Ideally, the area covered by a (or series of) map(s) should cover the whole surface extent specified by the user in the User Request Form (URF).

❖ ***Parameter/method used for assessing the spatial coverage of the area of interest:***

The extent of the area covered by the geo-information product with respect to the area specified by the user, can be measured using the area percentage that can be estimated either visually or automatically.

2] Overview map

An overview map or inset is a smaller map included within the context of a larger map. Insets can serve two main purposes: 1) to show the primary mapped area in relation to a larger, more recognizable area (a locator inset), 2) to provide a close up of a section or sections of the map. When the inset map is used to provide an overview, the targeted users should be considered in order to determine what locational information they need to properly fix the location of the area under study in their mind.

❖ ***Parameter/method used for assessing the overview map:***

Not only the presence of an inset map has to be checked but also its pertinence. This can be assessed thanks to the following questions:

- Can the location of the mapped area be easily identified?
- Is the map annotated with relevant location names?
- Is the affected area highlighted?

3] Coordinate graticules/grid

The graticule represents the projected position of the geographic coordinates at constant intervals, or in other words the projected position of selected meridians and parallels. The shape of the graticule depends largely on the characteristics and scale e.g. on the 1:50,000 topographic map, graticule lines or ticks can be represented at every 5 minutes and grid lines at every kilometer. The presence of graticules on a paper map can help to easily georeference the map once it is scanned and to use it in a GIS environment.

❖ ***Parameter/method used for assessing the coordinate graticules:***

The presence/absence of graticules and grids on a map will be examined. The pertinence of the spacing of graticules in relation with the scale of the map will also be assessed. The pertinence of coordinate labels and the precision (for paper maps and geospatial data) with regard to the end-user will also be examined. For instance, it is sometimes preferable to have the coordinates represented in decimal degrees in double-precision floating point, because, this format allows their easy integration in a GIS database.

4] Cartographic scale and printing size

The scale either indicates the amount of reduction that has taken place on a given map or allows the map user to measure distances. The cartographic scale determines the mapped space and level of cartographic detail possible. The presence of graphical scale (scale bar) in addition to a numerical ratio is encouraged. The ability of a scale bar to indicate distances, together with its ability to withstand enlargement and reduction of a map, make it the preferred format for inclusion on a map. The maximum distance value represented in a bar scale should always be rounded and easy to work with. In addition to the cartographic scale, the recommended print size should also be clearly defined on the map.

❖ ***Parameter/method used for assessing the cartographic scale:***

The presence/absence of the cartographic scale and of the recommended printing size will be checked on the map. In some cases the printing size is not explicitly written on the map but contained in a page description data that consists in a set of printing instructions (e.g. Postscript file).

5] Description of processing steps, information sources

A description of information sources and processing steps (orthorectification, classification, digitalization, visual analysis...), used for the production of geo-information, add confidence and credibility to the product. The description of processing information should clearly appear on the map and in the case of a geospatial database, it should be given in the metadata.

❖ ***Parameter/method used for assessing the description of processing steps, information sources:***

In a first place, the presence/absence of a description of information sources and processing steps will be examined. In a second place, the pertinence of the information sources and the approach used for processing it will be analyzed with regard to: 1) the output information required by the user and to 2) thematic and positional accuracy of the sources and of the product, detailing the assessment method used.

6] Interpretation text/report

The usability of a product (especially a map) can be enhanced by the presence of an interpretation text that gives information on the core elements represented in the map or contained in a geospatial database (origin of disaster, data, location, targeted users, etc.).

❖ ***Parameter/method used for assessing the interpretation text/report:***

In addition to the presence/absence of the interpretation text, its completeness, its clarity and the correctness of the formulation and spelling will also be examined.

7] Acknowledgement and sources

8] Name of the producer

9] Logos of the partners

The usability of the map is also reliant on the completeness of the information. Among the compulsory information that must be supplied by the service provider to the user, are the acknowledgement and the sources, the author and the contact information of the producer and the logos of the partners.

❖ ***Parameter/method used to check the 3 attributes:***

All the above cited attributes (points 7], 8] and 9]) should clearly appear on the map. Their presence/absence will hence be evaluated.

10] Media used

The data exchange format used for delivering a certain product to the end user will depend on the specific use context and is not generalizable to all classes of geo-information products (e.g. a map printed on water-proof media for use in tropical area during the rainy season is a typical need linked to a specific use context). The media used can also affect the decision on the map size. For instance, a service provider should not make an A5 map for an informative paper map such as a poster. Hence, the media used and the size of the map should also be consistent.

❖ ***Parameter/method used to check the media used:***

Information on the map medium should be clearly defined in the product requirements. Compliance to user needs, given in the URF and consistency with the map printing size are additional parameters to be checked during validation.

11] Readability

Readability refers not only to the visual perception of information contained in a product but also to cognition which deals with the users thought processes, prior experiences and memory. The principles of cognition are important because they explain why certain symbols work (i.e. communicate information effectively). To illustrate the importance of cognition, the examples of the use of different colours (e.g. blue or red) for representing the flood extent in different map products can be considered. For a certain user used to see flooded areas in blue, the presence of the red colour representing flood extent will be confusing since it might be associated with burned areas seen on previous maps.

❖ ***Parameters/methods used to assess readability:***

A set of parameters can be used to evaluate readability. These parameters will help to check if the service provider applied the basic cognitions of graphic semiology (choice of symbols, colours and typography, etc.):

- **Appropriate title, fitting with the content (contains topic, location, date)**

The title should be appropriate and fitting to the content of the map. It should also be complementary to the legend. The appropriateness and completeness of the titles will be assessed.

- **Adequacy of font size and colour of text**

A differentiation in the meaning of objects present in the same map requires variable fonts, with variables sizes and appropriate colour identification. For the font design in maps, it is necessary to decide on the font-family, its basic forms like size and the positioning of the type, dependant on the space that is left next to the other map elements. For example, in cartography with the variation in size, a differentiation in the meaning of certain objects in a group is possible, e.g. a smaller size could characterise a town with less inhabitants, a larger size more inhabitants. It is normally recommended to use a minimum difference of 2 points of font sizes for the different elements of the map (title, legend heading, legend definitions, data source, bar scale, map labels, etc.). It is also necessary to avoid mixing too many types of fonts in the same map.

- **Correctly placed labels**

Map labels placing, also called lettering, is important in the means of linguistic, practical, technical and aesthetic aspects. Illegible or non-existing labels on a map could cause damage to the users. Placement of letterings on the map should follow some basic cartographic rules.

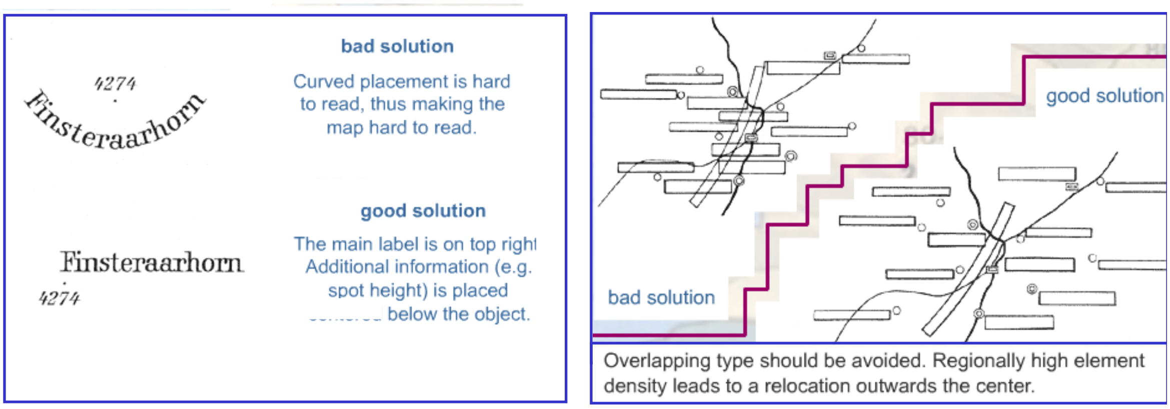

Figure 14- Examples of good and bad solutions for positioning of map labels

- **Adequate and differentiable Colours used for representing the different themes are; satisfactory visual contrast between background and map themes**

Colour conventions for qualitative and quantitative agreements will be checked.
Qualitative use of colour in mapping addresses points, lines, areas or symbols. The element's colour is seen as a qualitative value, i.e. it is not applying an amount to the elements. Qualitative value is expressed through colour hue and its intensity or saturation. The logic of use of different colours should be appropriate to user's habits: e.g.
Water – Blue; Vegetation – Green ; Land – Brown ; Temperature – Blue to Red .
In **quantitative** use of colours, value differences are best shown with a differing amount of one colour hue for one theme. Sequential schemes are for instance suited to ordered data that progress from low to high. Diverging schemes put equal emphasis in mid-range critical values and extremes at both ends of the data range.

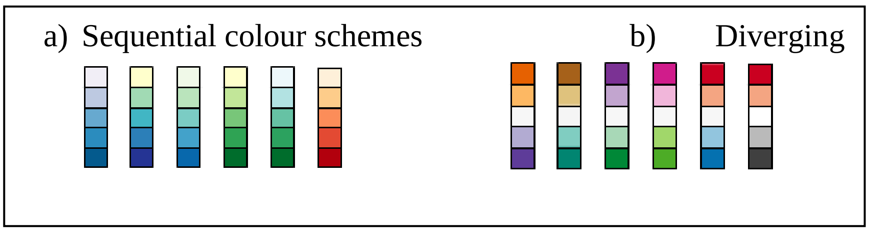

Figure 15- Example of conventional sequential (a) and diverging (b) colour schemes (http://www.colorbrewer.org)

The following basic rules should be respected when selecting qualitative and quantitative colour schemes for a map:

- The selected colours should allow the user to correctly match the colour on the map with the corresponding legend colour;
- The colours should convey a correct impression of how the feature changes in magnitude across the map area;
- The colour schemes are supposed to allow the comparison of quantitative data for features on two or more maps of the same area.

In addition to a qualitative assessment of the pertinence of the selected colours, the two following metrics will also be used to evaluate the contrast for colour schemes:

Colour brightness:

((Red value * 299) + (Green value * 587) + (Blue value * 114)) / 1000

Colour difference:

(maximum (Red value 1, Red value 2) - minimum (Red value 1, Red value 2)) + (maximum (Green value 1, Green value 2) - minimum (Green value 1, Green value 2)) + (maximum (Blue value 1, Blue value 2) - minimum (Blue value 1, Blue value 2))

Two colours provide good color visibility if the brightness difference and the color difference between the two colors are greater than a set range.

The range for colour brightness difference should be ≥ 125. Colour difference should be ≥ 400.

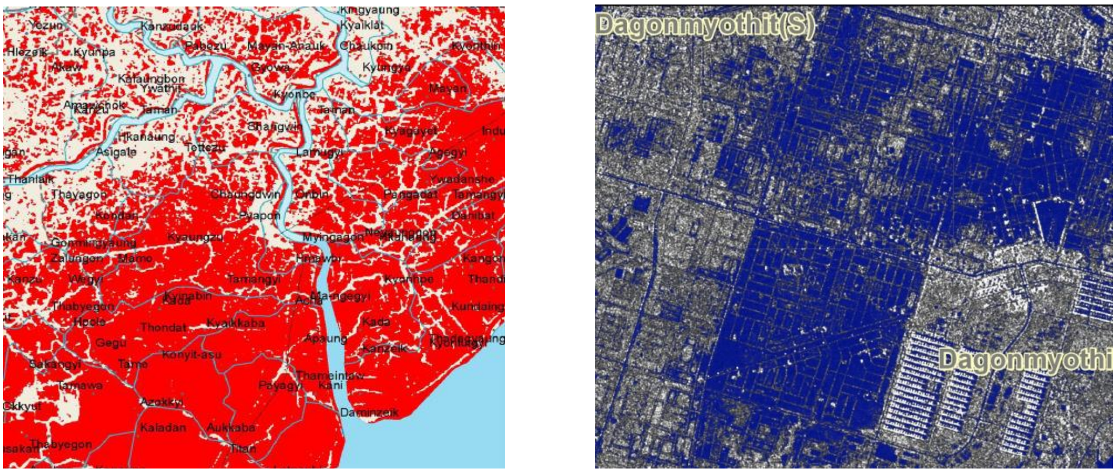

Figure 16- Example of bad map readability due to inadequate symbols' colours

These are subsets of two maps of areas affected by the tropical cyclone NARGIS produced at an interval of two days by the same service provider. The red and blue colours refer to <u>satellite detected water/wet areas</u> according to the legends of these two maps. The parameter that allows here to assess readability is the "Adequacy of the colours used to represent the different themes". This example shows how the readability of a map can be affected i) by the non respect of colour conventions and ii) by the inconsistency in the colours used to represent the same type of information in two products of a same service.

- **Symbols easily differentiable**

The various perceived differences in map symbols are usually described by the term visual variables. The differentiability of symbols is related to spacing, size, orientation, shape, arrangement and texture (combining the visual variables spacing and size) of visual variables. The pertinence of map symbols will hence be evaluated taking into account these basic visual variables. Besides, the respect of standards for geospatial symbology will be checked (e.g. the use of conventional topographic symbology for reference maps).

- **Absence of overlap between geo information layers**

This parameter is checked twice in the reliability of information content and in readability, because overlapping features affect both attributes (§ point 8] in reliability of information content).

12] Legend symbols are clearly defined

The legend is the map element that defines all of the thematic symbols on a map. Symbols that are self-explanatory and not directly related to the map's theme are normally omitted from simple thematic map legends. In contrast, for general reference maps, all the symbols should be defined even if self-explanatory. Special care should be taken to insure that symbols in the legend are identical to those used in the mapped area. Legend symbols should also be organized into groups based on a particular criterion (e.g. two groups can be formed according to whether the symbols represent natural or cultural features).

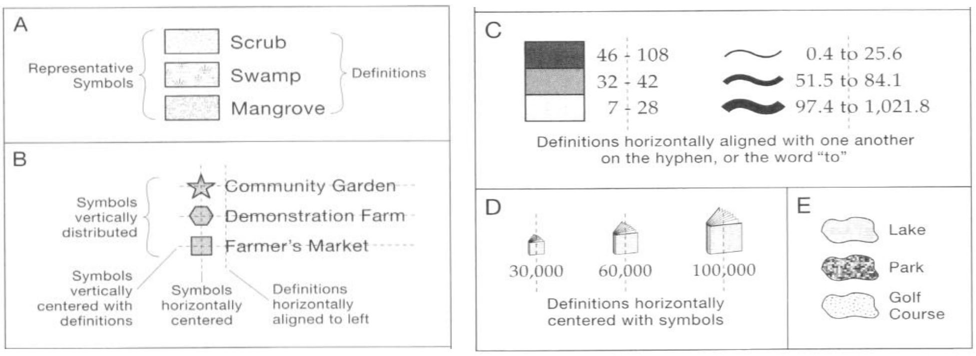

Figure 17 - Some basic rules for symbols layout in a legend

Figure 17 shows some basic rules for symbols layout in a legend (Slocum, McMaster et al. 2005); (A) The legend is composed of representative symbols and definitions, (B) Distribution and alignment of symbols and definitions, (C) Horizontal alignment of definitions composed of numeric ranges, (D) Horizontal positioning of symbols and definitions, (E) Irregular polygons used to represent areal data.

❖ ***Parameter/method used to check legend symbols:***

The presence/absence of a definition for each symbol in the legend will be checked. In addition the pertinence of the definition of symbols and their arrangement on the map legend will also be assessed.

13] Adequacy of the projection with the use

For some specific purposes, for instance for assessing areas, angles, or distances in a map, it is necessary to select an appropriate map projection that preserves a particular property. Projections that preserve either area or angles are called equivalent and conformal respectively. Equidistant projections preserve distances along some directions. The commonly used UTM projection, preserves shapes and direction, but distorts area and distance. Hence when areas have to be estimated from a map, it is better to use an equivalent projection. In some other situations, it is recommended that the local projection also is made available as a client option. This allows an easier integration in local geospatial databases.

❖ ***Parameter/method used to check adequacy of the projection:***

The projection should be clearly defined on the map and in the metadata. A check of the pertinence of the selected map projection with regard to user's need will be done. The possibility to request a specific map projection should be included into the requirements and into the URF.

14] Multilingual support

Most of the geo-information products for emergency response consider English as a reference language for communication. For non English speaking countries, one may ask how explanatory is the map? In some situations, it is necessary to have the toponyms or even the interpretation text in the national language. It is sometimes possible to just paraphrase the names in areas where Latin is not the base of the language e.g. Greek, Hebrew, Chinese, etc. Names can be simply transcribed[1].

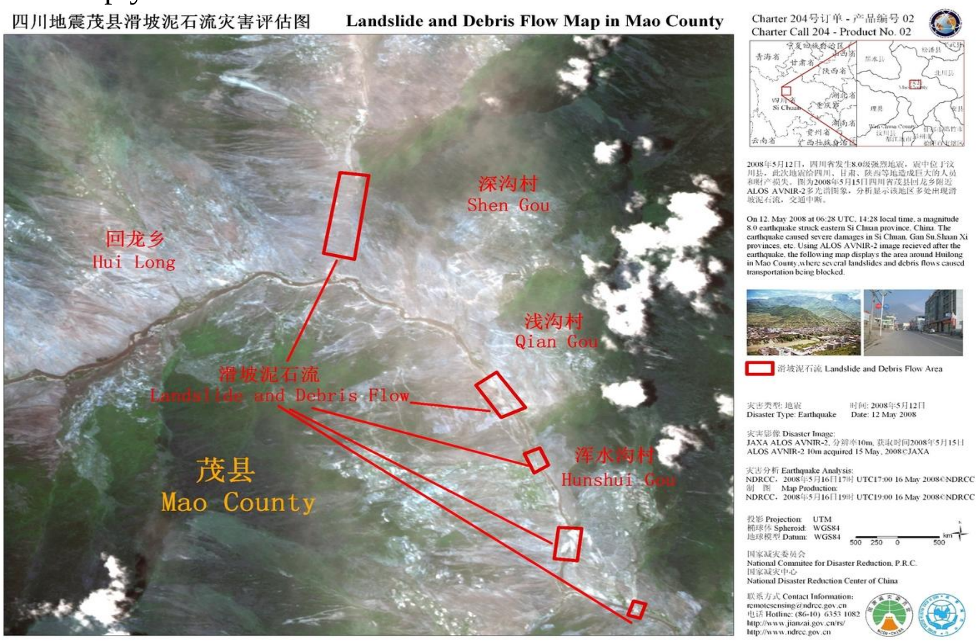

Figure 18- Example of a multi-lingual landslide and debris flow map for China earthquake occurred on 12 May 2008.

❖ ***Parameter/method used to check multilingual support:***

[1] *Transcription: is a method of replacing elements, fonts, characters or sounds however they may be written with characters or sounds of another language*.

The existence of a multilingual support for a map and its supporting documents is encouraged. Therefore the presence/absence of multiple languages and the pertinence of the language used with regard to user's requirements will be assessed. The possibility to request a specific language support should be included into the requirements and into the URF.

15] Metadata consistency

For validation purposes, some metadata sections are mandatory and hence need to be declared either directly on the map or in the metadata XML file for digital geographic data. The required metadata is relevant to content description aspects and is based on pre-defined standards (ISO 19115).

❖ ***Parameter/method used to check metadata consistency:***

The presence/absence of information related to the following metadata elements will be checked:

- Identification information (resource title, abstract, type, identifier, language)
- Classification of data and services (topic category)
- Keywords
- Geographic location (bounding box)
- Reference System
- Temporal reference- Quality and validity (spatial accuracy)
- Maintenance information
- Responsible organization (contact information)
- Information on license and copyrights
- Metadata on metadata (metadata point of contact; metadata language)

In addition, the compliance of metadata to pre-defined standards will also be assessed (e.g. check if metadata is compliant with ISO 19115 Geographic information – Metadata, or ISO 19131 Geographic information - Data product specifications).

16] Version number of the product

Of a particular importance for validation in general and for the user in particular is the availability of information on the versioning of a certain product. A version distinguishes between different releases of the same information resource that may occur over time. As some map products are sometimes subject to frequent updating, it is necessary to mention the version number either directly on the map product or in the metadata file.

❖ ***Parameter/method used to check version number:***

The presence/absence of versioning information either on the map or in the metadata file associated to the product will be checked.

17] Constraints related to access, use and sharing of information

Access limitations are restrictions and prerequisites for accessing the information resource. This information describes any constrains or legal prerequisites for accessing the information resource or its component products or services. This includes any access constraints applied to assure the protection of privacy or intellectual property and any other special restrictions or limitation on accessing the information.

❖ ***Parameter/method used to check constraints related to access, use and sharing of information:***

It is recommended to explicitly specify whether the product is governed by access limitations. Therefore the presence/absence of such information will be checked directly on the map or in the metadata file or in any other supporting document supplied by the service provider. Besides, the type of constraint will also be assessed. Examples of generic limitations that can be declared are: No Restrictions, Public, Sensitive, Classified.

18] Existence of additional fees

Contractual obligations or fees necessary to gain access to the information resource should also be referenced, mainly in the metadata file or in other related documents supplied by the service provider. This information should be free of ambiguity and all specific conditions related to the payment should be clearly mentioned so to avoid any bad surprise to the user.

❖ ***Parameter/method used to check the existence of additional fees:***

The presence/absence of information on additional fees will be checked, and the amount of the fees and the specific conditions will be evaluated with regard to the benefits of the products to the user.

19] Distribution liability

Any information regarding the liability assumed by the distributor should be clearly defined either directly on the map layout or in the metadata file for digital data. The statement of liability should clearly include the following information:

- liability regarding the input data (scale, resolution, spatial accuracy, date) used for generating the product,
- liability concerning the information content of the product (in relation with time constraints under which the product was generated),
- liability concerning the processing approach used for deriving the geo-information.

❖ ***Parameter/method used to check the distribution liability:***

The presence/absence of information on distribution liability will be checked directly on the map (for map products) or in metadata file for digital data.

4.6.4. Efficiency of the service

So far, the validation tackled mainly the products' attributes. The service that delivers the product to the users has also a series if attributes that can be evaluated through validation with the help of the users. Efficiency of the service is related to the infrastructure delivering the product(s). Ensuring the efficiency of the service is as important as validating the individual products. However evaluation of efficiency will be strongly dependent on the type of service: archive, proactive, reactive, alerts. The following attributes and their corresponding parameters will be used for assessing the efficiency of a service in an operational framework:

1] Delivery time from order

The time gap between the triggering and the delivery of the final product to the user is an essential attribute especially for full scale emergency-response services. The end-to-end service delivery time is based on four components: i) mobilization time (time for the user to activate a service), ii) EO data acquisition time (time to program the first set of crisis images with satellite tasking), iii) EO data production time (time to supply the first set of crisis images and the needed archive images called pre-images), iv) the value-adding time (time to produce and deliver the first products).

- ***Parameter/method used for determining the time from order:***

The delivery time can be measured (only by users) by the number of hours, days or months and can be checked by comparing the declared delivery time in service requirements and the actual delivery time to the users.

2] Delivery cost

The cost of the products delivery is essential to assess the benefit of a service to the users. The delivery cost should normally be justified by the benefits the users get from a particular service.

- ***Parameter/method used for assessing the delivery cost:***

The delivery cost can be measured by the amount of money necessary for the provision of a particular service or product. This real cost can be cross checked with the declared cost given in the service requirements/specifications.

3] Technical support

The existence of a technical support is also an important aspect describing the efficiency of a service. The technical support here is understood as a team or unit that provides assistance to the users before, during and after the products delivery. The technical support is also expected to ensure products inclusion and publication in the service portal.

- ***Parameter/method used for assessing the technical support:***

The **presence/absence** of a multilingual center and the availability of a 24/7 option (allowing to activate the service) can help to assess the efficiency of a service and its reactivity in the case of a disaster. This information can be verified either in the metadata or it can be directly mentioned on the map or in service specifications. It has to be compared with requirements.

4] Frequency of update

Updating frequency especially for rapid maps and early warning services (e.g. real-time services) can also contribute to assess the efficiency of a service. In case of rapid maps, updating frequency is essential for a continuous information support during response. In the prevention phase, it helps to anticipate protective actions and allows to respond quickly to the emergency.

- ***Parameter/method used for determining the frequency of update:***

This attribute can be represented in terms of minutes, hours, days or even months. The higher the frequency, the better is the efficiency of the service. However, the evaluation of this parameter will strongly depend on the type of delivered product. For instance, for past disaster maps or for risk maps, the updating frequency is defined according to the user needs and is not as essential as for rapid mapping products. This parameter will also be checked in the documentation supplied by the service provider or in service specifications, with respect to requirements.

5] Integrity

Integrity is the extent to which geo-information product is delivered correctly by the service without any alteration in the delivery process (aspects of handling, distribution and information delivery or access). This assumes that the validation expert traces the service output as soon as it is produced at the provider's unit and checks against the delivered product once it reaches the end-user.

- ***Parameter/method used for assessing the integrity:***

Checking the integrity means to look at the media or the system used to deliver the product and assess its **compliance** (yes/no) to standards and its **adequacy** (yes/no) for the type of information it is supposed to supply. The integrity can be evaluated by checking the product before and after delivery to the end user and by assessing the changes that may occur during the delivery process.

4.6.5. Validation summary checklist

The following checklist summarizes attributes, parameters and methods used to perform the validation.

Validation categories	Attributes	Parameters	Methods
Reliability of the information content	1] Thematic accuracy (based on *in-situ* data) Decide/propose the most important themes for each product type and focus on them	**Quantitative measures :** - Overall acc., -Commission error, -Omission error, -Producer's acc., -User's acc., -Kappa coefficient, -Conditional Kappa, (Congalton 1991)	- Probability-based sampling design - Comparison with *in-situ* data - Interpretation of field work
	2] Thematic consistency (based on consistency check with other sources, excluding *in- situ data*)	**Quantitative measures :** Same as thematic accuracy **Qualitative and quantitative systematic measures :** - Composition of a cell, -Fragmentation index, -Heterogeneity index, -Shannon entropy index (Strahler, Boschetti et al. 2006)	- Reclassification of the concerned regions or areas of interest - Digitization of certain elements from reference satellite imagery, topographic maps, etc. - Independent visual interpretation - Overlay with vector data - Photo interpretation - Comparison with adequate land cover data sets - Grid based qualitative validation (based on reference data)
	3] The absolute positional accuracy of the information	Absolute Root Mean Square Error	Comparison with ground surveys
	4] The relative positional consistency of the information	Relative Root Mean Square Error	Comparison with reference data (satellite/map/vector)
	5] Time gap	Time interval between the event of interest and the information source (based on selected priority layers)	-Check Metadata -Compare with satellite catalogues
	6] Information on occlusion (clouds, artefacts) expressed as a percentage of the spatial extent	Presence/absence	Check in Metadata, interpretation text
	7] Information on occlusion (clouds, artefacts, ..) in the form of a mask representing occluded areas	Presence/absence	Visual (on the map)
	8] Overlap between geo information layers	-Presence/absence -Pertinence	-Visual (on the map) -Semi-automated (e.g. line segments, point features, homogeneous segments)
	9] Semantic definition of information content (either public or *ad hoc*)	- Presence/absence - Completeness	-Check in Metadata -Check if a reference for definition source is available on the

			map
	10] Information on the spatial detail of information sources	- Presence/absence of spatial resolution (for image data) - Presence/absence of nominal scale (for vector data)	-Check in Metadata, report or text supplied by the service provider
	11] The methodology used for accuracy assessment	-Presence/absence - Pertinence	Check in Metadata, report or text supplied by the service provider
	12] Credibility	-The scientific and or social reputation and experience of the source -The independence of the source from political/economical interest on the information delivered	-Validation expert's experience -Experience record of the source
Consistency of the	1] Consistency between absolute positional accuracies (spatial details)	-Ratio between declared absolute positional accuracy of the product and declared absolute positional accuracy of information sources -Ratio between declared absolute positional accuracy of the product and absolute positional accuracy of information contained in the product	Check in metadata. Visual estimation, computer assisted assessment.
	2] The relative positional consistency across different feature sets in the same product	Relative Root Mean Square Error	-Derived from absolute positional accuracy -Cross-check with GCPs obtained from reference satellite/map/vector
	3] Relative time gap between most significant features	Number of hours, days, months or years	-Check in Metadata
	4] Respect of generalization rules	- Pertinence of symbolic representation according to different scales and semantic hierarchy, -Pertinence of metric representation according to different scales and semantic hierarchy.	- Visual (on the map) -Check in Metadata
	5] Consistency between map and legend symbols	-All map symbols are included in the legend	Visual (on the map)
	6] Compatibility between the geographic coordinate/projection systems of the different features (or geo-information layers) included in the same product	Pertinence	-Visual (on the map) -Check in Metadata - Check data file properties

information support	7] Topological consistency	- Adjacency of features - Cover/inclusion - Presence of gaps - Overlapping - Closure of polygons - Connection of networks - Presence of dangles - Continuity of features (across tiles)	-Visual (on the map) -Computer aided topological tools
	8] Attributes consistency	- Data type compliance - Value range - Filling of required fields	- Visual (on the map) -Computer aided
	9] Consistency between declared and effective representation scale	- Consistency of scale bar - Consistency of numerical scale	Visual or computer aided, control points
Usability of	1] Spatial coverage of the area of interest	Percentage of the area of interest covered by the product	-Visual (on the map) -Computer aided
	2] Overview map	- Presence/absence - Pertinence	Visual (on the map)
	3] Coordinate Graticules/Grid	- Presence/absence -Pertinence of spacing -Pertinence of coordinate labels (precision)	Visual (on the map)
	4] Cartographic scale and printing size	-Presence/absence	-Visual (on the map)
	5] Description of processing steps, information sources	- Presence/absence, -Pertinence	-Visual (on the map) -Check in Metadata
	6] Interpretation text/report	- Presence/absence - Completeness, - Correctness of formulation and spelling	Visual (on the map)
	7] Acknowledgments and source	Presence/absence	Visual (on the map)
	8] The name of producer	Presence/absence	Visual (on the map)
	9] Logos of partners (where a number of organisations are responsible for the content and publication of a map, each organization should receive equal prominence)	Presence/absence	Visual (on the map)
	10] Media Used	- Digital (GIS-ready, image-ready, graphic, office-ready) -Analogical (paper, water-proof, plastic, other media) and fitness for its intended use, -Consistency with the printing size.	Visual

the product	11] Readability	- Appropriate title, fitting with the content (contains topic, location, date) - Adequacy of font size and color of text - Labels are correctly placed - Colors used for representing the different themes are adequate and differentiable; visual contrast between background and map themes is satisfactory - Symbols easily differentiable - Absence of overlap between geo information layers	- Visual (on the map) - Computer-aided
	12] Legend symbols are clearly defined	-Presence/absence - Pertinence	Visual (on the map)
	13] Adequacy of the projection with the use	Pertinence (e.g. area estimation requires equal area projection, in some case national projection system is required)	- Check in Metadata -Visual on the map
	14] Multilingual support	Pertinence of the map and supporting document language(s)	Check in map and interpretation report
	15] Metadata consistency	- Identification information (resource title, abstract, type, identifier, language) - Classification of data and services (topic category) - Keywords - Geographic location (bounding box) - Temporal reference - Quality and validity (spatial accuracy) - Responsible organization (contact information) - Information on license and copyrights - Metadata on metadata (metadata point of contact; metadata language)	-Check in Metadata if all information required for validation is present -Check if Metadata is compliant with pre-defined standards (e.g. ISO 19115 and ISO 19119)
	16] Version number of the product	- Presence/absence	-Check in Metadata -Visual (on the map)
	17] Constraints related to access, use and information sharing	- Presence/absence - Type	Check in Metadata, map layout, report supplied by the service provider
	18] Existence of additional fees	- Presence/absence - Amount and conditions	Check in Metadata, map layout, report supplied by the service provider
	19] Distribution Liability : a statement of the liability assumed by the distributor of a data set or information resource	Presence/absence	Check in Metadata, map layout, report supplied by the service provider
	1] Delivery time from order	Number of hours, days, months	Cross check between service requirements (specifications)

Efficiency of the service				and actual delivery time
	2]	Delivery cost	Amount	Cross check between service requirements (specifications) and actual delivery cost
	3]	Technical support	- 24/7 option available - Multilingual call center	- Check in Metadata, map layout, report supplied by the service provider - Questionnaire - Check in service requirements (specifications)
	4]	Frequency of update (in case of series of maps)	Number of hours, days, months	- Check in Metadata, map layout, report supplied by the service provider - Check in service requirements (specifications
	5]	Integrity	Compliance to standards of the media used for product delivery	Check product before and after delivery to end user

Table 2- Summary checklist for validation attributes

4.6.6. Sampling scheme

For both thematic and positional accuracy computation, it can be necessary to apply a sampling scheme, since usually it is impossible to validate the whole dataset. In this paragraph general sampling indications will be given. Since it is not possible to consider all possible cases, the validation expert should take into account these indications and adapt them to each specific case using common sense. The sampling scheme will depend on the peculiarity of each map. Just general criteria can be given at this stage. In any case the sampling design is a critical point, because it can affect the assessment results.

There are many kinds of data that can be necessary to sample. For example if products from a certain service provider are to be validated, the objects to sample are “products”, in some other cases there can be a product constituted by many tiles, so the objects to sample are “tiles”. Hereinafter the objects to be sampled will be addressed generically as “elements”.

All the elements should be divided into homogeneous groups, if necessary, and a sample from each group should be validated. For example if there are tiles of a base map representing a large territory, with both flat and mountainous areas, both could be taken into account separately. Also, if necessary, each element should be divided into homogeneous strata, for example if there are more layers, each layer should be dealt with separately.

At least the 10-15% of the elements should be validated, even if the number can vary according to particular cases: with a very large amount of data it could be possible to consider no more than 50-100 elements, on the contrary, with a very small amount of data at least 10-20 elements should be considered.

It is important to distinguish between the sampling for the positional accuracy assessment and for the thematic accuracy assessment for each element or within each element stratum.

Positional accuracy assessment. Within each stratum, the sampling scheme, if possible, should reproduce approximately a grid. In that way all parts of the map can be validated. It is really important to sample map borders, to verify the presence and entity of border effects. Depending on the subject of the map, the density of the sample can vary. To have significant statistics of the results the samples should include at least 20 points, in really difficult conditions the number could decrease till 10, but better results can be achieved considering 50-100 points.

Thematic accuracy validation. About thematic validation, instead of single points, polygons should be preferred. It is possible to consider different sampling schemes (Congalton and Green 1993).

- Random sampling: this is the sampling scheme that gives the best statistical results, about samples independency;
- Systematic sampling: the samples are taken at a regular interval starting from a random point. It permits to uniformly cover the area of interest;
- Stratified random sampling: data are divided into strata, for example one stratum for each class, or even more strata in one class, if there are significant differences among different zones, and then each stratum is randomly sampled.

It often happens that the selected points or polygons are not accessible on the field, or it is impossible to recover information about them, so it can be necessary to move them. Anyway those points or polygons must be moved to a more accessible place taking into account the sampling scheme criteria.

5. CONCLUSION

5.1. MAIN CONSIDERATIONS UPON THE VALIDATION PROCESS AFTER ITS IMPLEMENTATION

After the experience acquired in the implementation of the protocol, the following considerations have been originated upon the validation process:

- The protocol is a systematic collection of product attributes to be checked and of parameters and methods that allow performing the assessment;
- The protocol application level, the number of parameters that can be practically checked, depends on the context (type of product, user needs, available reference data);
- The availability of reference data is a crucial issue for validation process;
- Additional reference data (e.g. GPS-tagged photos) can be provided by local authorities to help the validation process;
- The protocol has been applied to practical cases and proved to be useful to highlight issues in the delivered products, e.g.:
  - arguable definition of normal water level in flood map;
  - difference between the cartographic scale of the maps and the scale/resolution of information contents;
  - some confusion may occur between burned area related to activation specific event and burned areas related to previous fires;
  - limits in detecting water in urban areas with SAR data;
  - a reference map used as background for emergency products is usually preferred by the user with respect to background satellite images.

5.2. MAIN RECOMMENDATIONS AND SUGGESTIONS FOR NEXT STEPS

To improve the validation process it is important:

- To develop the interface with service providers, to enhance a positive feedback that helps them to continuously improve the products' quality;
- To develop the interface with users to refine user requirements understanding.
- To cooperate with users to jointly define validation ranges for the most important attributes and parameters (with respect to product type);
- To define a "protocol for fast validation", that allows performing the check of the product without any reference data, and to try to assess its usefulness;
- To define a list of mandatory attributes to be checked depending on the type of the product and on the time frame given for validation;
- To experiment the use of mathematical models, pre-event knowledge and ancillary data to reduce the need of reference data.

5.3. CONCLUDING REMARKS

The validation protocol described in this document aims at ensuring a consistency of the validation process by providing guidelines for the assessment of the products attributes. The protocol was purposely defined at a generic level in order to accommodate with the different types and families of emergency services and products.

The application of the validation protocol can be performed at different levels depending on the following main factors:

- The type of product to be validated (e.g. rapid situation assessment, rapid damage assessment, situation assessment, damage assessment…). The type of product addresses priorities between attributes to be included in the validation process and their validation ranges;
- The specific users' needs. Users' needs can change priorities among attributes to be included in the validation process and their validation ranges with respect to defaults or agreements, e.g. users

could need an updated area of interest or a tradeoff between time delivery and accuracy;

- The availability of reference data. On the one hand, availability of reference data enables for a complete validation process, namely including the assessment of attributes defined under “Reliability of the information content”. On the other hand, in case of absence of reference data, it is still possible to (partially) assess the product, focusing on of attributes defined under “Consistency of information support” and “Readability”. This latter approach, is considerably less informative than the former, but given its fast application, its reduced cost, and the wide applicability, deserves to be considered and assessed.

The presented approach considers the need to achieve a balance between i) a comprehensive validation of all aspects of a product and ii) a practical validation that helps users to be more effective in their operations and service providers to improve the quality of the delivered products.

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Abstract
Europe is making a significant effort to develop (geo)information services for crisis management as part of the Global Monitoring for Environment and Security GMES) programme. Recognising the importance of coordinated European response to crises and the potential contribution of GMES, the Commission launched a number of preparatory activities in coordination with relevant stakeholders for the establishment of an Emergency Response GMES Core Service (ERCS). GMES Emergency Response Services will rely on information provided by advanced technical and operational capabilities making full use of space earth observation and supporting their integration with other sources of data and information. Data and information generated by these services can be used to enhance emergency preparedness and early reaction to foreseeable or imminent crises and disasters.

From a technical point of view, the use of geo-information for emergency response poses significant challenges for spatial data collection, data management, information extraction and communication. The need for an independent formal assessment of crisis products to provide operational services with homogeneous and reliable standards has recently become recognized as an integral component of service development. Validation is intended to help end-users decide how much to trust geo-information products (maps, spatial dataset). The focus, in this document, is on geo-information products, in particular those derived from Earth Observation data. Validation principles have been implemented into a protocol, as a tool to check whether the products meet standards and user needs. The validation principles, methods, rules and guidelines provided in this document aim to give a structure that guarantees an overall documented and continuous quality of ERCS products.

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