BAS user requirements

BAS gebruikersvereisten

Ministerie van Verkeer en Waterstaat

Rijkswaterstaat

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Colofon

Uitgegeven door: Rijkswaterstaat Adviesdienst Geo-informatie en ICT (RWS AGI)
Derde Werelddreef 1
2622 HA Delft
Postbus 5023
2600 GA Delft

Informatie:
Telefoon: 015 275 71 46
Telefoon alg.: 015 275 75 75
Fax alg.: 015 275 75 76

Uitgevoerd door: dr. J. Vogelzang
dr. W.T.B. van der Lee (RIKZ)
ir. L.M.Th. Swart

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Versie-geschiedenis: 1.0–1.6 zijn de Nederlandstalige versies;
2.0–2.6 zijn de Engelse versies uit de *BAS Product Description* versie 1.0–1.6;
3.0 is het eerste document in onderhavige zelfstandige vorm, met aanvullingen;
3.1–3.3 aanscherpingen en toevoeging hoofdstukken 5, 6 en 7
3.4–3.5 na bespreking in projectteam, schrappen summiere kostenbatenhoofdstuk en met kleine verbeteringen Willem van der Lee

Inhoudsopgave

1 Introduction

The current standard product for Rijkswaterstaat monitoring soundings is a depth map on a 20 m × 20 m grid, obtained from interpolation of shipborne single beam echo soundings with a track distance of 200 m. The interpolation is done with the DIGIPOL software, which has been especially developed for this purpose. These "vaklodingen" are part of the bathymetric monitoring program. They are ordered by RIKZ and the soundings are performed by the regional directorates of Rijkswaterstaat. The DIGIPOL interpolation is done either by RIKZ or by the regional directorates, depending on what provisions have been made.

The Bathymetry Assessment System (BAS) constructs depth maps from the following data:
1. satellite images (radar images and optical images);
2. flow data from a tidal model on a coarse grid;
3. a limited number of echo soundings.

At this stage the BAS is fit for use in monitoring soundings above shallow parts of the Wadden Sea and the Western Scheldt [J. Vogelzang, *BAS validatie Eemsgeul*, Report AGI-GAR-2003-24, RWS-MD, Delft, 2003]. The advantage of the BAS is that it needs less echo soundings than the traditional method because it uses the physical information in satellite images. A track distance of 600 m is sufficient, thus allowing more efficient generation of depth maps. The BAS is developed and owned by the company ARGOSS.

As a result of the first workshop in March 2003 with the RIKZ and the regional directorates, the algorithms, software and production process of ARGOSS were evaluated. The result was mainly positive. However, the BAS software and processing chain were not yet on a level required for a reliable operational service. A project was accepted in the National User Support Programme Earth Observation (Nationaal Programma Gebruikersondersteuning Aardobservatie, GO). This project aims at improving the BAS software and production chain to a level required for an operational service, and to check this by an external audit.[1]

In order to be able to formulate the audit requirements and to establish the requirements on the BAS service, Rijkswaterstaat establishes its user requirements on a bathymetric service. This is done in the current

1 Project *Towards implementation of the BAS within Rijkswaterstaat*, NIVR-GO project 2.1 IB-31. Half of the costs of the partners (Rijkswaterstaat Adviesdienst Geo-informatie en ICT, ARGOSS and AeroVision and IBAS ICT for the audit) are financed from this programme. The activities are executed under Rijkswaterstaat project *Inbedding BAS*, RWS AGI 27931 and 27933.

document.[2] The user requirements pertain not only to the accuracy of the BAS maps, but to the whole production chain, including items like the format of input soundings delivered by RWS, the turn-around time for the BAS processing, the reliability of the service, etc.

Two *classes of bathymetric service* based on the BAS are being distinguished. In the *class 1 service*, the echo soundings are collected by RWS and the BAS processing is performed by ARGOSS. This service fits easily in today's practice. In the *class 2 service*, ARGOSS takes responsibility of the production of bathymetric maps, including the echo soundings needed. This service fits well in the philosophy that the government should make use of commercial services whenever possible. These service models are presented in chapter 2.

The user requirements can be split into two groups: requirements on the BAS product (technical requirements) and requirements on the BAS service (organisational requirements). The *requirements on the BAS product* deal with precision, reliability (concerning delivery of a depth map), uniformity (comparability of the depth maps for all areas in the Netherlands), and data format. These requirements are discussed in chapter 3. The *requirements for the BAS service* deal with the delivery time and place, quality of the production process and the service, its reliability, the continuity of the BAS service and the cost. These requirements are discussed in chapter 4.

Although strictly speaking not belonging to the user requirements, this document also contains other remarks of interest to the BAS process. For the proper application of the BAS map, the quality needs to be validated. This can be done either by validation of the product itself or by focussing on the quality of the production process. Because no procedures have been established yet to validate a depth map, we focus on the quality of the process of production of a depth map with BAS. During this process, input data are used that determine, or influence, the quality of the resulting map. In chapter 5 the parameters of these input data are discussed. In chapter 6 the validation of the depth map as a product itself is discussed.

2 Because of the requirements of the GO programme and the international publication of its results, this document is in English.

2 BAS service models

Two different classes of bathymetric service based on the BAS are being distinguished.

1. **Class 1 service**, in which the echo soundings are collected by RWS and the BAS processing is performed by ARGOSS. This service fits easily in today's practice;
2. **Class 2 service,** in which ARGOSS takes responsibility of the production of bathymetric maps, including the echo soundings needed. This service fits well in the philosophy that the government should make use of commercial services whenever possible.

In section 2.1 the class 1 service is discussed. Section 2.2 is dedicated to the service class 2.

2.1 Service class 1, scheme and milestones

Service class 1 is a production process in which ARGOSS and RWS share the work. Therefore both parties depend on each other to produce the required product. RWS orders ARGOSS to apply the BAS to shipborne single beam echo soundings with a track distance of 600 m supplied by RWS. The necessary satellite images will be provided by third parties and flow data in the relevant time frame for the relevant area will be supplied by ARGOSS. This will lead to a depth map which will be delivered to RWS. Figure 2.1 shows the class 1 service scheme.

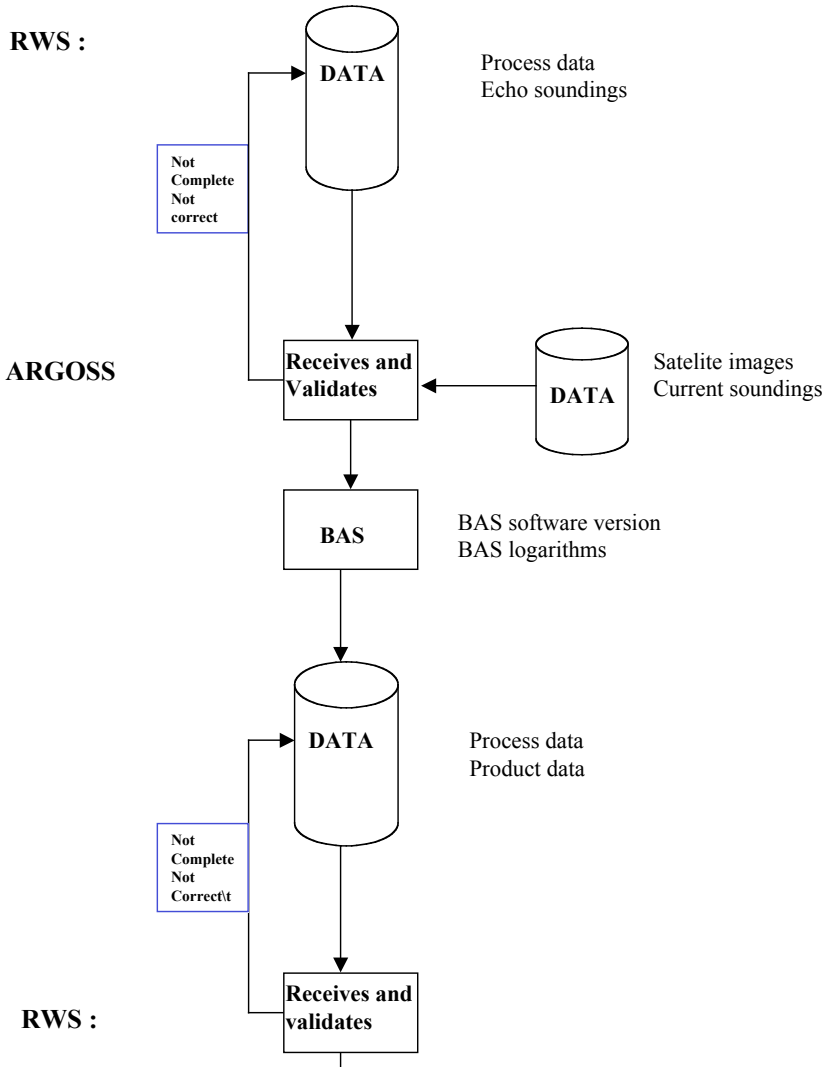

Figure 2.1 Class 1 service scheme

The milestones are:

1. Reception, validation and acceptation of echo sounding data from RWS by ARGOSS.
2. Reception and validation of satellite images from third parties by ARGOSS; generation and validation of flow data by ARGOSS.
3. BAS map production by ARGOSS.
4. BAS map delivery by ARGOSS to RWS.
5. Reception and validation of the BAS map by RWS.

2.2 Service class 2

Service class 2 is a production process in which RWS orders ARGOSS to deliver depth charts of specific areas using the BAS method. ARGOSS is responsible for collecting all data needed, including the echo soundings. Figure 2.2 shows the class 2 service scheme.

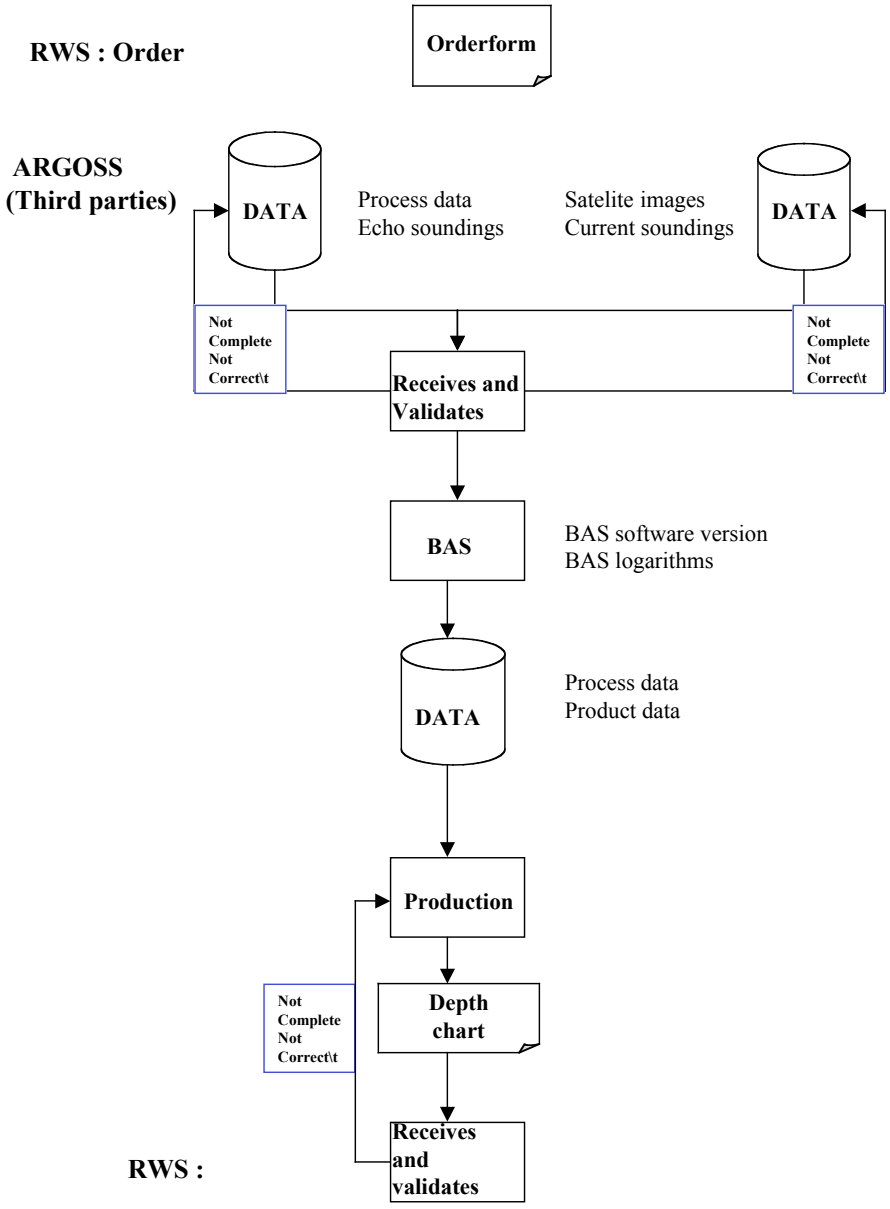

Figure 2.2 Class 2 service scheme

The milestones for the class 2 service scheme are :

1. Reception and validation of echo sounding data and satellite images from third parties by ARGOSS; generation and validation of flow data by ARGOSS.
2. BAS map production by ARGOSS.
3. BAS map delivery by ARGOSS to RWS.
4. Reception and validation of the BAS map by RWS.

Since RWS in this service class is no longer able to monitor the quality of the echo soundings, this type of service needs extra user requirements. The quality of the hydrographic service within RWS is described in the QMS; a similar quality management system will be necessary in this service class. See also § 5.1.

3 Requirements on the BAS product

The BAS user requirements can be split into two groups: requirements on the BAS product (technical requirements), discussed in this chapter, and requirements on the BAS service (organisational requirements), discussed in chapter 4.

The *requirements on the BAS product* are:

1. **Precision**: the precision of the BAS map must not be worse than that of the current standard DIGIPOL map.
2. **Reliability**: data acquisition should be reliable enough to guarantee delivery of a depth map.
3. **Uniformity**: depth maps must be comparable for all areas in the Netherlands and for all kinds of areas in terms of quality, resolution, etc.
4. **Data format**: the BAS map is on a North-oriented grid with 20 m grid size in an ASCII (e.g., XML) format.

These items are discussed in the next sections.

3.1 Precision

Nowadays monitoring soundings are collected from ships with a single beam echo sounder along transects 200 m apart. The pattern of transects is fixed and defined in such a way that the transects are as much as possible perpendicular to banks and channels. The soundings are interpolated to a North oriented grid with a mesh of 20 m using the DIGIPOL interpolation software. The resulting DIGIPOL map is the standard monitoring product.

The error in a DIGIPOL map consists of three components:

1. **Slowly varying errors** or systematic errors in the echo soundings. These errors vary over distances ranging from several hundreds of meters to tens of kilometers. They are caused by errors in measuring position and orientation of the ship. Together these errors add up to about 5 cm. Both DIGIPOL and BAS copy these errors and will therefore exhibit the same systematic errors. Note that sand volume calculations require a minimal systematic error (see the remark at the end of this section).
2. **Noise in the soundings**. This varies from point to point and has a standard deviation of about 10 cm. More precisely: the standard deviation is 9 cm at a depth of 10 m and 11 cm at a depth of 20 m. This error averages out in sand volume calculations.
3. **Interpolation errors**.
   a. If individual soundings fall within a grid cell, DIGIPOL assigns the average value to that cell. Such a cell becomes a support point in the interpolation process. The depth in a support point will be quite precise because of the averaging.

b. DIGIPOL interpolates between the support points which causes an additional error that increases with distance to the support points. This error consists of the pure interpolation error and the error due to the idealisation of the bottom topography. The standard deviation of the interpolation error can be 50 cm or more, depending on the shape of the bottom between the support points.

There are very few cases in which additional soundings are available to check the accuracy of the DIGIPOL interpolation. However, a method has been developed to estimate the interpolation error made by DIGIPOL without using additional soundings [C.J. Calkoen, *Nauwkeurigheidsstudie DIGIPOL*, Report A135, ARGOSS, Marknesse, 1998]. This method is implemented in the most recent version of DIGIPOL; validation by RIKZ is under study at the time of writing.

The expected difference between an independent sounding and the depth value in the corresponding grid cell of a DIGIPOL map will vary with position. When the grid cell happens to be a support point the difference is expected to be small. When the grid cell lies far away from the support points, the expected difference will be much larger. The simplest measure for the quality of a standard depth map is therefore the spatial averaged standard deviation relative to independent soundings.

The BAS is an interpolator like DIGIPOL. The difference is that the BAS uses physical information in satellite images to steer the interpolation process, thus allowing larger distances between the support points and, hence, between the transects of echo soundings. Both the BAS and DIGIPOL copy slowly varying errors. In support points the BAS will, like DIGIPOL, yield a more accurate estimate of the depth than between the transects (though the BAS has some freedom to deviate from the echo soundings). Outside the support points the BAS bases its interpolation on the information in satellite images. Image noise and interpretation errors will cause an interpolation error.

From these considerations it is concluded that the (spatially) averaged standard deviation relative to independent soundings is a good measure for the accuracy of both the DIGIPOL and the BAS map.

The average standard deviation of a BAS map should not exceed that of the current standard product, a DIGIPOL interpolation of soundings with 200 m transect distance. The actual value of the spatially averaged standard deviation is currently under study.[3]

3 The interpolation error made by DIGIPOL increases quadratically with the distance to the support points (the soundings) [C.J. Calkoen, Nauwkeurigheidsstudie DIGIPOL, Report A135, ARGOSS, Marknesse, 1998], and from this, the spatially averaged error can be estimated without using additional soundings. Without independent soundings, the precision of a BAS map can be calculated from this DIGIPOL precision and the difference with the DIGIPOL interpolated map, see [J. Vogelzang, L-band SAR voor bathymetrische toepassingen, report AGI/31505/GAR006, January 2005, § 3.4] and the ARGOSS-memo

It must be remarked that the user requirements on precision are expected to become more severe in the future. There is a need to make sand volume calculations on a time scale from 3 to 6 years, which is already difficult to achieve with todays precision. Activities like gas extraction in the Wadden Sea may lead to the need for depth maps with higher accuracy (and/or frequency) in order to assess the net effect of bottom subsidence and increased sedimentation. However, as shown above, such applications require minimal systematic errors which are mainly induced by the echo soundings, and less by the DIGIPOL interpolation or the BAS processing.

3.2 Reliability

Monitoring soundings are gathered with a frequency ranging from once every three years for the Western Scheldt and the coastal zone to once every six years for the Wadden Sea and Eastern Scheldt, depending on the speed of erosion or sedimentation and the importance for shipping. In order to guarantee continuity in the monitoring data set, a sounding must be performed in the year it is planned.

The BAS needs not only satellite data but also echo soundings and flow data. Radar images require suitable wind and current conditions while optical images require cloudless conditions. As a rule of thumb, satellite data can be acquired in a period ranging from six weeks before to six weeks after collecting the echo soundings, unless a heavy storm occurs which may change the bottom drastically. So far, archived satellite data have been used without major problems. If Rijkswaterstaat decides to use the BAS on a routine base for a significantly large area, all possible satellite data should be acquired. In that case, ARGOSS should make provisions with the providers of satellite images.

Data delivery is guaranteed to a sufficient level for DIGIPOL maps. For the BAS service, delivery of depth maps with a quality as agreed upon must be guaranteed by ARGOSS; as a consequence this could eventually mean that ARGOSS deliveres a depth map produced with a conventional technique if the acquisition quality parameters are in disfavour to the application of BAS.

3.3 Uniformity

The accuracy of the depth maps may not depend on the area under consideration: depth maps of the Wadden Sea must have the same

[Methode om de nauwkeurigheid van BAS en DIGIPOL te vergelijken, February 2003]. The error strongly depends on the type of bottom topography and is largest at tidal channels, but there DIGIPOL and BAS behave very different [J. Vogelzang, BAS validatie Eemsgeul, report AGI-GAR-2003-24, September 2003]. In Opnametechnieken vaklodingen (N. Wiegmann et al., report AGI-2005-GSMH-012, May 2005) this method is used for Vak 3 in the Western Scheldt, but for the first time also a comparison between the DIGIPOL interpolation of 200-meter sounding transects and independent multibeam data is made [§ A.1]. This yields, for this particular area, a DIGIPOL interpolation precision of σ = 25 cm.

quality as those of the Western Scheldt, assuming, of course, comparable variability in the depth. One must be able to compare BAS maps and DIGIPOL maps without noticing differences caused by the production method.

Note that maps based on multibeam soundings cannot be compared with DIGIPOL maps, because a multibeam map shows many details that are not present in maps based on interpolation of single beam soundings.

3.4 Data format

The BAS map must be delivered in a north oriented grid in the RD system with a grid size of 20 m. The X- and Y-coordinates of the lower left corner of each grid cell should be a multiple of 20 m. The BAS map should be in an ASCII (e.g., XML) format.

3.5 Echo soundings (in case of class 2 service)

In the case of class 2 soundings, ARGOSS takes responsibility of the collection of single beam echo soundings with 600 m track distance. These soundings should be produced with identical precision to the RWS soundings. In particular, recording of the horizontal and vertical position of the ship should be done with Real Time Kinematic (RTK) GPS in order to minimise slowly varying errors. These data should be stored in ASCII format. Provisions need to be made for storing metadata.

4 Requirements on the BAS service

The user requirements can be split into two groups: requirements on the BAS product (technical requirements), discussed in the previous chapter, and requirements on the BAS service (organizational requirements), discussed hereafter.

The *requirements for the BAS service* are:

1. **Delivery time and place**: the BAS map has to be delivered before November 15 of the year the map was ordered. It has to be delivered at RIKZ.
2. **Quality**: the production process and the service should meet the quality standards required by RWS.
3. **Reliability**: the production process and the service should be reliable. The BAS software should be stable and robust enough to guarantee delivery of a depth map.
4. **Continuity**: the BAS service must be guaranteed for a period of six years at least.
5. **Cost**: the BAS service should lead to efficiency improvements for RWS.

These items are discussed in the next sections.

4.1 Time and place

The BAS map should be delivered before November 15 of the year in which the soundings are collected. Delivery time is not crucial for bathymetric monitoring purposes. The BAS maps are delivered at RIKZ, addressed to the officer responsible for the programme of monitoring soundings, unless agreed otherwise.

4.2 Quality

The requirements on accuracy of the depth map have been defined in the previous chapter. The production process and the production software should be well defined and robust. It should always be possible to trace back the map production process to detect errors. ARGOSS should be accessible during office hours for questions and comments. In more detail, the requirements are:

- Every milestone in the production process must be documented. The documentation includes data on the method used, the time frame in which the data were collected, the parties involved and the software version used.
- All process documentation must be stored for a period of 6 years or until a new map has been made of the same area.
- All process documentation must be available to RWS and needs to be supplied on request within a time frame of 48 hours.

- The BAS quality assurance must include standard forms and formats for documentation and storage of all documents and data.
- All data required for delivering a depth map should be stored along with the process data and will be stored for a period of 6 years or until a new chart has been made of the same area.
- Every change in the production process within a period in which ARGOSS is contractually obligated to deliver depth maps must be validated by ARGOSS and approved by RWS before implementation.

In case of the class 1 service, ARGOSS should validate and accept the echo soundings supplied by RWS prior to the production of a BAS depth map.

Validation of the BAS product by RWS will be part of the delivery process. RWS can return the delivered product if validation demonstrates that the product and/or service requirements are not met.

ARGOSS is required to define the process and to formulate its quality assurance measures in such a way that it will comply with the RWS demands of traceability of product to source, verification of all process steps (milestones), configuration management of BAS software and availability of documentation.

4.3 Reliability

ARGOSS must honour its obligations towards Rijkswaterstaat. The description of the production process and of the software used should be up to date and provide all necessary information for ARGOSS employees to fulfil their tasks.

4.4 Continuity

If Rijkswaterstaat decides to use the depth map service based upon the BAS on a routine base for a significantly large area, it must be guaranteed for a period of six years at least (the cycle for monitoring soundings).

4.5 Costs

The BAS service should lead to efficiency improvements for RWS. Because of the financial system used by Dutch governmental organisations like Rijkswaterstaat, this means that the 'out of pocket' costs for Rijkswaterstaat using the BAS should be lower than those using conventional techniques.

The out of pocket costs for the conventional technique consist of ship time, man hours of the crew and for data processing including DIGIPOL interpolation. Use of BAS will result in executing echo soundings at transects 600 m apart instead of 200 m and hence in a saving. The costs of the BAS service must be lower than this saving.

A comparison on precision, reliability, uniformity, continuity and cost-benefit of techniques for depth maps used for monitoring is currently under study. In this study, the costs of echo soundings with and without use of the BAS will be compared for two specific cases: an area in the Western Scheldt and one in de Wadden Sea.

5 Indicators of the quality parameters for the BAS process

5.1 Introduction

The BAS process yields a depth map with a certain quality. For the proper application of the map – and possibly for the acceptance of the delivered product – the quality needs to be validated. This can be done in two ways.

- One could *validate the product itself*, i.e., the BAS depth map could be validated by a numerical comparison with independent depth data.
- One could argue that if the focus is on the quality of the *process* and the individual steps within it, then the product should be on the required quality level.

Because no procedures have been established yet to validate a depth map (see chapter 6), we focus on the quality of the process. This is done by an assessment of the production process and its quality assurance described by ARGOSS in *The bathymetry service chain*. Furthermore, during the process of production of a depth map with BAS, input data are used that determine, or influence, the quality of the resulting map. In the following sections, the parameters of these input data that give an indication of the quality of the end product are discussed. These parameters should be delivered as *metadata* of the BAS product by ARGOSS.

In chapter 6 the validation of the depth map as a product itself is discussed.

5.2 Input data: echo soundings

The quality of the echo soundings will be quaranteed in the future via the Quality Management System (QMS), the Rijkswaterstaat standard description. Please refer to the documents concerning QMS.

5.3 Input data: radar images

- Only images of well-known satellites should be used: ERS, ENVISAT and/or RADARSAT. A list of the image products used should be supplied, likely PRI images.
- The parameters of the images used should be supplied: satellite, sensor, image mode, date, time, orbit number, frame number.
- Clear images of the area serve to assess the quality of the radar image and to check for ship tracks and other features not related to bottom topography.

- The administration of masked areas should be supplied: areas not suitable for processing due to ship tracks and other features not related to bottom topography.

5.4 Input data: optical images

In order to discriminate between tidal flats and channels and for better positioning of the land-water boundary and masking, optical images may be used.

- Only images of well-known optical satellites should be used, like LANDSAT, SPOT an other; no obscure sources should be used.
- The parameters of the images used should be supplied: satellite, sensor, image mode, date, time, orbit number, frame number.
- Clear images of the area serve to assess the quality of the optical image.
- The administration of masked areas should be supplied: areas not suitable for processing due to disturbing features not related to bottom topography.

5.5 Input data: current vectors

- A list of used current vectors (position, current velocity and current direction) should be supplied.
- The model used to calculate the current vectors should be named, the model schematisation, the way it was calibrated and validated.

5.6 Input data: hydro-meteo conditions

- A graph of the wind speed should be supplied at a station not further away from the mapping area than 100 km (e.g.), during the time interval between acquisition of the satellite image and the echo soundings, to guarantee that storms did not disturb the bottom topography over that interval.
- Information should be supplied on the atmospheric stratification, that could influence the wind-seasurface-interaction and hence the radar cross section.

5.7 Processing data

- Version number of the used software.
- Log of the steps and decisions taken during processing including the motivation of the decisions.
- Log of the parameters used.
- Name of the operator for the different processing steps.

5.8 Auxiliary products

- Clear images of the simulated radar images.
- Clear images of the simulated current fields for each of the simulated radar images.

- The values of the gain parameters in the forward model for each of the simulated radar images (together with the simulated current fields, this can be used to calculate the simulated radar image).
- The value of the terms of the minimised cost function.
- The weights of the terms of the minimised cost function.

The correct interpretation of the last three parameters needs some specialistic knowledge. Therefore the choices for these parameters must be motivated in a log.

6 Validation of the depth map

At this moment there is no clear procedure how Rijkswaterstaat should validate depth maps. One could argue that we focus on the quality assurance of the *process* and the individual steps within it, then the product should be on the required quality level. This is why the production process and its quality assurance, described by ARGOSS in *The bathymetry service chain*, is assessed by an audit. Furthermore, the input data used during the process of production of a depth map with BAS can give an indication of the quality of the end product. These are discussed in chapter 5.

The *werkgroup hydrografie* is currently developing a procedure to validate depth maps, including a BAS map. Till now, BAS maps were produced as pilots parallel to echo soundings that suffice to calculate a depth map with DIGIPOL. The way to validate the BAS map, based on a selection of the echo soundings on 600-meter transects, by comparing it with the DIGIPOL map based on the complete set of soundings on 200-meter transects, is best described in [J. Vogelzang, *L-band SAR voor bathymetrische* toepassingen, report AGI/31505/GAR006, January 2005, § 3.4] and the ARGOSS-memo [*Methode om de nauwkeurigheid van BAS en DIGIPOL te vergelijken*, February 2003]. See note 1 in § 3.1.

If the BAS is used on a routine base, only echo soundings on 600-meter transects will be acquired, because this will lead to the prospected efficiency improvement. The validation as done in the pilots will not be possible anymore and independent soundings will be needed to validate the BAS depth map. In *Opnametechnieken vaklodingen* (N. Wiegmann et al., report AGI-2005-GSMH-012, May 2005) the DIGIPOL interpolation of 200-meter sounding transects for Vak 3 in the Western Scheldt is compared to independent multibeam data, but for shallow water and tidal flats multibeam is not available. Probably, the BAS depth map can be validated in a manner similar to what is done in laser altimetry: use of areas with known depth and separate soundings diagonally over the mapped area. Development of such procedures must be done in practice and requires several years, which takes the actual definition of the validation and acceptance procedure outside the scope of this project.