BEAM 4 – AN EFFICIENT DEVELOPMENT PLATFORM
FOR OPTICAL EO DATA

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ABSTRACT

BEAM is an application suite which facilitates the utilisation, viewing and processing of the Envisat MERIS, AATSR and ASAR data products as well as ERS-ATSR, MODIS, AVHRR and ALOS products. BEAM has become a widely accepted, freely available software used throughout the Envisat scientific user community. Thanks to its 100% pure Java implementation, it is available for the Windows, Linux, Max OS X, Solaris and other Java enabled operating systems. Today, BEAM is in use by many end users of MERIS and AATSR data and also the Envisat Cal/Val team makes significant use of BEAMs analysing, visualizing and processing capabilities. The success of the open source BEAM software package was also made clear during the ENVISAT and MERIS User Workshops in 2003, 2004 and 2005, in that a growing number of users are already using or are willing to use the API (application programming interface) of BEAM for their own developments using the Java™ programming language.

1. INTRODUCTION

With the launch of ENVISAT in 2002 the need for a software toolbox became evident. The generic ENVISAT N1 format was cumbersome for users to decode. The capabilities of image processing software at that time was inappropriate for a scientific exploitation of MERIS and AATSR and there was a need to make specific processing and correction tools, such as the smile correction for MERIS, available to a wide user community. Additionally, the product concept of MERIS and AATSR required documentation and explanation. Consequently, ESA decided to develop a dedicated collection of tools for MERIS and AATSR, the BEAM Toolbox. During the past years this toolbox has grown driven by user requirements. Today the software has more than 1200 registered users, providing important feedback which is used to continuously improve the functionality as well as its performance and ergonomics.

2. BEAM toolbox constituents

The BEAM toolbox is composed of 4 major constituents: a desktop application for visualization and analysis of optical EO data (VISAT), 11 scientific data processors, extensive help on BEAM, MERIS and AATSR data products and the BEAM Application programming interface (API) for software developers.

These constituents are applicable to data of numerous optical instruments as well as – with limited scope – to some radar instruments. This list of currently supported sensors and instruments is presented in Table 1.

### Table 1: Currently supported instruments

<table>
<thead>
<tr>
<th>ESA Missions</th>
<th>Third Party Missions</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENVISAT MERIS AATSR ASAR</td>
<td>ALOS AVNIR2 PRISM</td>
</tr>
<tr>
<td>ERS ATSR SAR</td>
<td>Terra, Aqua MODIS</td>
</tr>
<tr>
<td>Proba Chris</td>
<td>Metop, NOAA AVHRR/3</td>
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<tr>
<td></td>
<td>Landsat Thematic Mapper</td>
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<tr>
<td></td>
<td>Generic netCDF</td>
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BEAM is used in 3 different, distinct ways:

- VISAT tool users open, browse, visualize and analyze interactively EO data and export the results to other tools;
- Data processor users generate new data products, assess performance of algorithms and visualize the results; they may integrate the data processors in local processing chains;
- Developers contribute to the BEAM open-source project: they provide readers, processors, map-projections etc. and use BEAM libraries in their own development projects

2.1. VISAT

VISAT is BEAMs visualization, analysing and processing application. It has a clear and intuitive user interface allowing new users to get started quickly.
VISAT permits switching between a product browser providing overview over multiple open products within a tree view and comprehensive pixel information view to display geophysical values, interpolated tie-points and quality flags at the same time. VISAT supports overlay of bitmasks, which corresponds to product quality flags but which can also be defined by the user. The analysis tools of VISAT include geolocation information, statistical parameters calculated on the whole image or on a user defined region of interest, inspection of spectra, plots of transects, histograms and scatter plots. The tools menu of VISAT is composed of scientific data processors and additionally the band arithmetic tool, which provides mathematical expressions to generate new bands within a product, map projections, orthorectification as well as convolution filters. Products that have been changed or to which colour tables, pins, ROIs have been added can be saved in DIMAP format and later reopened with all attached information preserved.

2.2. Data processors

BEAM includes currently 11 data processors which are delivered with the standard installation. Additional processors are available from the Plug-In Website. The standard delivery includes, among others, the smile correction for MERIS, a flexible SST calculation for AATSR and 2 different Level 3 generation tools. Both tools generate an averaged, mapped product based on a set of input product products. The covered area as well as the output pixel size and the map projection can be chosen. The Level 3 binning processor implements the forward resampling, where each pixel of an input product is submitted to exactly one binning cell of the output product. The mosaic processor steps through the output product and searches for each binning cell corresponding pixels in the input products. The statistical behaviour as well as the visual appearance of the generated products differ and the choice of the tool depends on the user requirements. All processors can be run in batch mode as well as from within VISAT.

2.3. Help

BEAM help is providing an introduction to the BEAM toolbox and its components. All functions are described in detail and with application examples. The help of all data processors is prepared in a unified way, including a section about the scientific background and a second section about the usage of the processor and its processing parameters.

The Java API documentation is a separate package and has been developed with Java Doc to provide an interactive tool to explore the API as well as to guide developers fast to the detailed documentation of every class. Code examples of data processors complement the developers help.

2.4. JAVA API

All BEAM applications have been implemented in Java programming language. The complete source code together with an introductory architecture overview and the detailed JavaDoc documentation is part of the BEAM download package. BEAM components are currently used in numerous developments outside of the BEAM development project. This includes various scientific studies resulting in processors for new products, such as MERIS Land Products, the Case 2
Regional Processor, the FAPAR Processor or the FUB Water Constituents processor. Other applications are VISAT extension tools (Globcolour diagnostic dataset tool, AVISA reference data set collection), product generation (Globcover processor, AlbedoMap processor, WAQSS software) and Web Services (EO CalVal Portal, Nodes for ESA Grid and SSE, SISCAL).

3. Software architecture

3.1. Main concept

The building blocks of the BEAM system have been designed with respect to reusability and extendibility. Figure 2 shows how the high-level BEAM applications have been build on lower-level frameworks which offer programming interfaces for extension on their own. Therefore BEAM can be reused or extended at different levels of complexity.

The main concept used for the BEAM architecture is simple and based on
1. a common, unified data model designed specifically for remote sensing products,
2. imaging, processing and analysis modules exclusively operating on this data model,
3. data readers and writers for distinct EO file formats which convert into/from this data model.

Such a product model is the key element of the BEAM architecture. It has been designed to ingest the information contained in the data products of a wide range of imaging sensors and make this data accessible through the BEAM application programming interfaces.

The BEAM software system realises this concept by providing an API which represents the static product data model and extension points, e.g. for the product readers and writers. The imaging, analysis, and data processing functions are separated into modules with as little as possible mutual dependencies. BEAM can read Level-1b and Level-2 data from the sensors MERIS, (A)ATSR and MODIS, furthermore the data from ASAR, AVHRR and AVNIR. It can also read NetCDF EO data formats conforming to the Climate and Forecast (CF) Conventions. The BEAM-DIMAP format is the standard I/O data format used by VISAT and the default output format for the BEAM data processors.

The BEAM-DIMAP format has been developed in order to consistently support the generic product model. It is a specialisation of the DIMAP format, a format which has been developed by Spot Image and CNES. The most important feature of the BEAM-DIMAP format is its simplicity: The raster data is stored in flat binary files, one file for each band, line-wise. The metadata is stored in a separate XML header. BEAM can efficiently read from and write to BEAM-DIMAP data products.

3.2. BEAM 4 module architecture

The BEAM development started in 2002 with a comparable narrow objective but has evolved significantly and the complexity of the software has grown over the years. Some design elements which were good choices in the beginning turned out to be no longer suitable for the increased functionality. One example is the layer management. In BEAM 3.x there are several data overlays possible: bitmasks, regions of interest, no data, pins, world map, shapes. However, each of these layers has its own API, management and user interface, because a generic layer model was not considered necessary in the beginning. Therefore it was decided to refactor the architecture of BEAM from version 3 to version 4. The “outside” look-and-feel has been modernised and the internal architecture has become significantly more clear, concise and efficient.
One core concept is the module architecture. BEAM 4 has been decomposed into modules which are all independently developed, modified and versioned. The BEAM 4 module architecture is therefore an ideal platform to start the development of new applications. Figure 4 shows a general schematic of the BEAM 4 module architecture with the main modules beam-core, beam-processing and beam user interface. Building on these higher level applications, such as VISAT or the map projection, are constructed.

A second important concept which has been implemented strictly throughout all BEAM modules are extensions. Each module has dedicated extension points, which are clearly defined and documented interfaces. The host module provides extension points and client modules provide extensions. Extensions add functionality to the host module. Extension points are reflected in the VISAT interface by grouping of functions. For example, the BEAM core provides an extension point for reader (Figure 5). Figure 1 shows in the expanded import menu how the various client modules (different product readers) appear as menu entries.

4. User community

The open source approach allows for distributed development resulting in a faster rate of growth, flexibility and stability. The dedicated Wiki for exchange of knowledge and exchange of BEAM plugins can be visited under www.brockmann-consult.de/beam-wiki/. This is used as a platform for inserting user requirements by the user community, for questions and answers as well as exchange platform for experiences. A Plug-In page provides third party, voluntary extensions, which have been developed using the BEAM API and providing additional functionality to VISAT or scientific data processors.

5. Conclusions and Outlook

With BEAM 4 a platform is available which provides essential functions to the user community for analyzing and processing of optical EO data. The module software architecture is easy to maintain and implements a clear concept for extensions and upgrades.

The currently planned evolution of BEAM concerns mainly support for additional sensors, including Chris and SMOS, as well as new data processors, e.g. for water quality parameters of lakes. These developments use the new module concept; however, the potential of this architecture is larger and would allow the development of operational processing systems as well as development of completely new toolboxes for different applications. The BEAM platform would be an ideal tool for preparation and operational exploitation of data from the future Sentinel satellites.

The open source concepts as well as the user community tools foster such developments. A prerequisite would be the long term maintenance of the BEAM open source project, which is not ensured currently.