The ESA BEAM Toolbox and Development Platform

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KEYWORDS: Satellite remote sensing, Earth observation, European Space Agency, image processing toolbox, application development platform

The BEAM project [1, 2] was kicked-off 10 years ago, in June 2002, in response to a call by the European Space Agency (ESA). The objective was to provide a set of open source tools and application programming interfaces for scientific use. An open source policy was chosen in order to ensure technical transparency, foster the implementation and exchange of innovative algorithms, and avoid proprietary licensing restrictions. BEAM originally aimed at the exploitation of remotely sensed data products from Envisat’s MERIS, AATSR and ASAR instruments.

After its first release, the BEAM toolbox was very well received by data users and also software developers. While being further developed over the years, 24 version updates have been released so far, turning the basic Envisat toolbox into the BEAM Development Platform for general Earth Observation data visualisation, analysis and processing. Due to its open and modular architecture and its extendibility through plug-ins BEAM comprises a large number of tools supporting a variety of Earth Observation sensors and data formats. Today, BEAM counts a few thousand users and is actively developed and maintained by Brockmann Consult. External collaborators contribute to the BEAM source code and external organisations provide additional
plug-ins. The most recent versions can be downloaded from http://www.brockmann-consult.de/beam/.

The main components of BEAM are:

- **VISAT** - An intuitive desktop application used for Earth observation data visualisation, analysing and processing
- A set of scientific data processors running either from the command-line or invoked by VISAT
- The command-line tool “gpt” (graph processing tool) is used to execute processing graphs made up of operators nodes developed using the BEAM graph processing framework (see Java application programming interface below)
- A data product converter tool allowing a user to convert raw data products to the BEAM-DIMAP standard format, to NetCDF, HDF, GeoTIFF, or RGB images
- The development platform, a rich Java™ application programming interface which provides ready-to-use components for remote sensing related application development and plug-in points for new BEAM extension modules. Besides a number of extension points such as product reader and writers, the BEAM application programming interface comprises the graph processing framework which is used to rapidly create raster data processors. The VISAT rich client platform is used to develop rich graphical user interface applications based on BEAM VISAT

The most important extension points provided by the BEAM Development Platform are:

- Product I/O application programming interface – allows to extend BEAM for new data product readers and writers
- Graph processing framework - This application programming interface allows to rapidly develop new data processors (processing “operators”) and to combine them to processing graphs
- VISAT rich client platform – Used to build efficient Earth observation imaging applications for the desktop
The following features are provided by the BEAM/VISAT desktop application:

→ Very fast image display and navigation even of giga-pixel images
→ Advanced layer management allows adding and manipulation of new overlays such as images of other bands, images from web map servers or ESRI™ shapefiles
→ Rich region-of-interest definitions for statistics and various plots
→ Easy bitmask definition and overlay
→ Flexible band arithmetic using arbitrary mathematical expressions
→ Accurate reprojection and ortho-rectification to all common map projections,
→ Geo-coding and rectification using ground control points
→ Store and restore the current session including all opened files, views and layers
→ A standard set of scientific data processors which includes
  ‣ Level 3 binning and mosaicing (all sensors)
  ‣ Collocation (all sensors)
  ‣ Expectation-minimization (EM) and K-means clustering, linear spectral unmixing (all sensors)
  ‣ Radiance-to-reflectance, smile effect correction, cloud probability, SMAC atmospheric correction, case 2 water constituents (MERIS)
  ‣ Sea surface temperature (AATSR)
  ‣ Fluorescence line height, maximum chlorophyll index, normalized difference vegetation index (all sensors)
  ‣ And many more

The supported sensors are MERIS, AATSR, ASAR of Envisat, ATSR and SAR of ERS, ALOS, AVNIR-2 of PRISM, MODIS of Aqua and Terra, CHRIS of PROBA, AVHRR of NOAA-KLM and MetOp, VGT of SPOT, TM of Landsat and many more available as plug-ins. Furthermore BEAM supports opening files of a number of formats commonly used in the modelling and remote sensing domain such as GeoTIFF, NetCDF CF and HDF-EOS.
The BEAM development platform is the basis of a number of very efficient Earth observation data applications. Among those, the most prominent application is NEST, a specialisation of BEAM comprising many new readers, processors and graphical user interface extensions dedicated to the exploitation of synthetic aperture radar (SAR) data.

In the latest version 4.10 (May 2012), BEAM has been enhanced by a number of efficient and user-friendly tools supporting validation activities. A number of new features are resulting from a fruitful collaboration with the NASA Ocean Biology Processing Group (OBPG). OBPG is developing SeaDAS, a comprehensive image analysis package for the processing, display, analysis, and quality control of ocean color data. OBPG is currently replacing the SeaDAS 6 frontend using BEAM’s VISAT rich client platform. The new SeaDAS 7 frontend will also offer a number of great new tools for SeaDAS users. All SeaDAS command-line processing tools (l2gen, l3gen, etc) will be callable from modern and intuitive user interfaces. The new SeaDAS 7 frontend will of course support all data products offered through the OPBG, namely MODIS, SeaWiFS, CZCS, OCTS and VIIRS.
Recently ESA has selected the BEAM development platform as basis for the Sentinel exploitation tools. The main objective of the development of Sentinel Exploitation Tools is to provide users a means to work with all standard data products generated by the sensors on board of the new Sentinel satellites which will be launched 2013/2014. This includes fast visualisation, comprehensive analysis and effective processing of the data. The requested way to achieve this is to extend the existing ESA toolboxes BEAM and NEST by dedicated reader plug-ins for the Sentinel user products. This way, the majority of the existing NEST (for the Sentinel 1 data products) and BEAM (for the Sentinel 2 and 3 data products) features are applicable to these data products.

In addition to a number of dedicated readers, the Sentinel 2 atmospheric correction processor for Sentinel 2’s multi-spectral instrument (MSI) level 1 data will be integrated into the BEAM toolbox. Developing efficient tools for the Sentinel data products is a challenging task and is due to the greatly increased data volumes. Single Sentinel data products are magnitudes larger than their Envisat counterparts, and they do provide much more information, including increased spatial and spectral resolution coupled with the provision of per-pixel annotations such as geo-location, sensing time, measurement uncertainties and other quality information. The Sentinel exploitation tools will make available the following data products for a maximum of existing BEAM and NEST visualisation, analysis and processing tools:

- Sentinel 1 (SAR): level 0, level 1 single look complex, level 1 ground range detected, ocean level 2 products (wind, wave, currents)
- Sentinel 2 (MSI): level 1B, level 1C, level 2A (surface reflectance product)
- Sentinel 3 (OLCI): level 1B, water level 2, land level 2
- Sentinel 3 (SLSTR): level 1B, water level 2, land level 2; synergy level 1C, level 2; VGT P, S1, S10