Sean Bailey – NASA GSFC
Norman Fomferra – Brockmann Consult

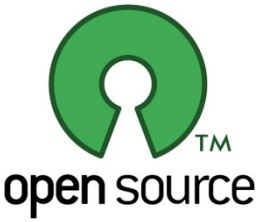
SeaDAS and BEAM User Tools

Data Processing, Analysis and Exploitation Tools

International Ocean Colour Science
Meeting 2013
Darmstadt, 07.05.2013

The BEAM Project

- ESA project kicked off for exploitation of **Envisat** data
- Open source, agile software development
- Platform neutral, 100% Java



- BEAM today
  - 24 public releases, hundreds of module updates
  - Thousands of users worldwide
  - Dozens of projects use and support it (ESA, EU, EUMETSAT, NASA)
  - Dozens of supported sensors and data formats, data processors
  - Dozens of tools and data processors
  - Hundreds of universities, institutes, companies use it

- Active user forum (daily posts), frequently visited website, issue tracker, tutorials, manuals

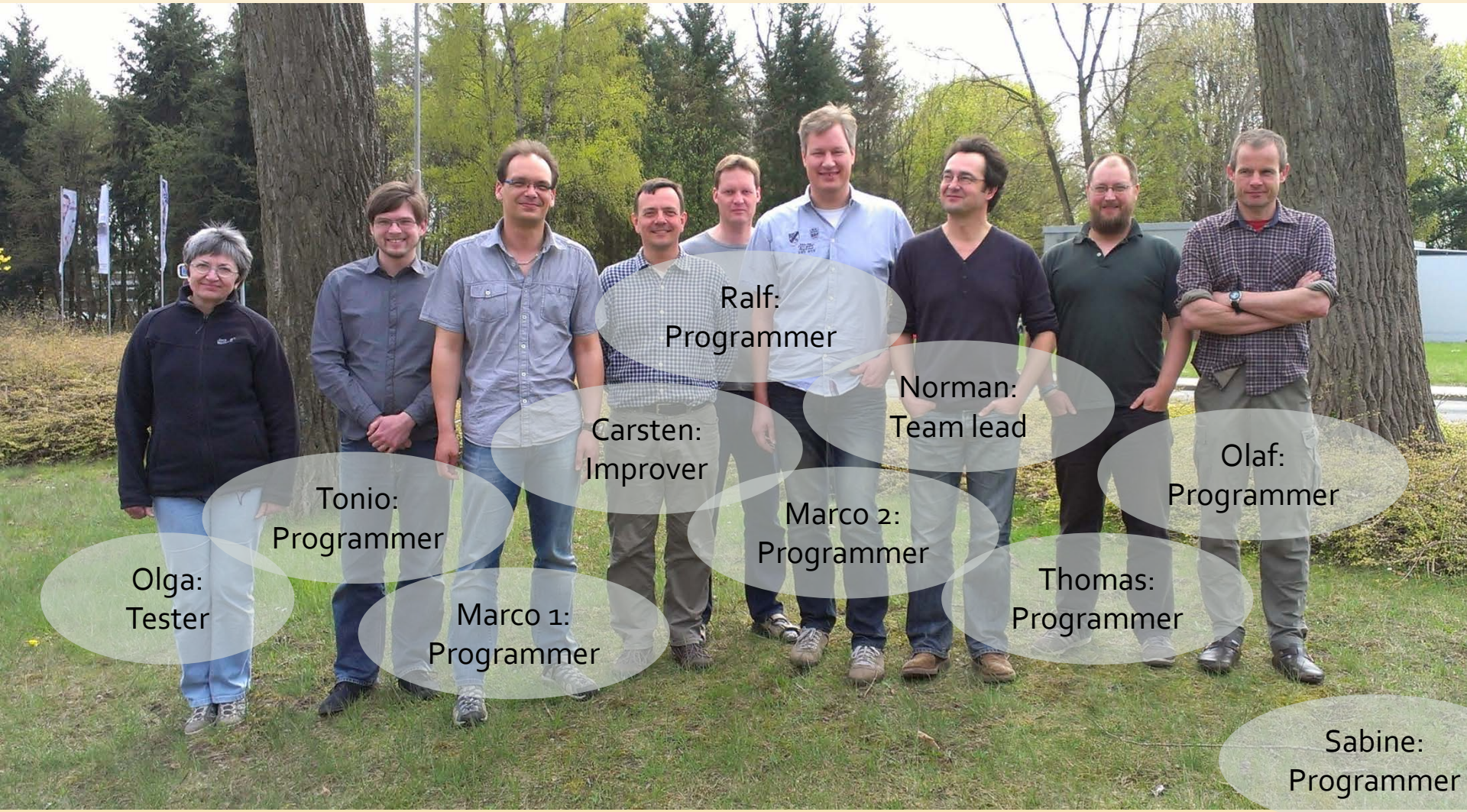
The BEAM Project

- Which once was the "Basic Envisat (A)ATSR and MERIS Toolbox" became a general **EO Toolbox and Development Platform**

- Supported sensors: MERIS, (A)ATSR , ASAR, Chris, AVNIR-2, PRISM, MODIS, AVHRR/3, TM Thematic Mapper, SPOT-VGT, MODIS, SeaWiFS, VIIRS, OCM, …
- Generic formats: NetCDF/CF, HDF-EOS, GeoTIFF, ENVI

- Derived Toolboxes based on the BEAM Platform
  - NASA SeaDAS 7 Ocean Colour Processing Toolbox
  - ESA NEST & InSAR Processing Toolbox
  - ESA LeoWorks Remote Sensing Training Software

The BEAM Project - Team

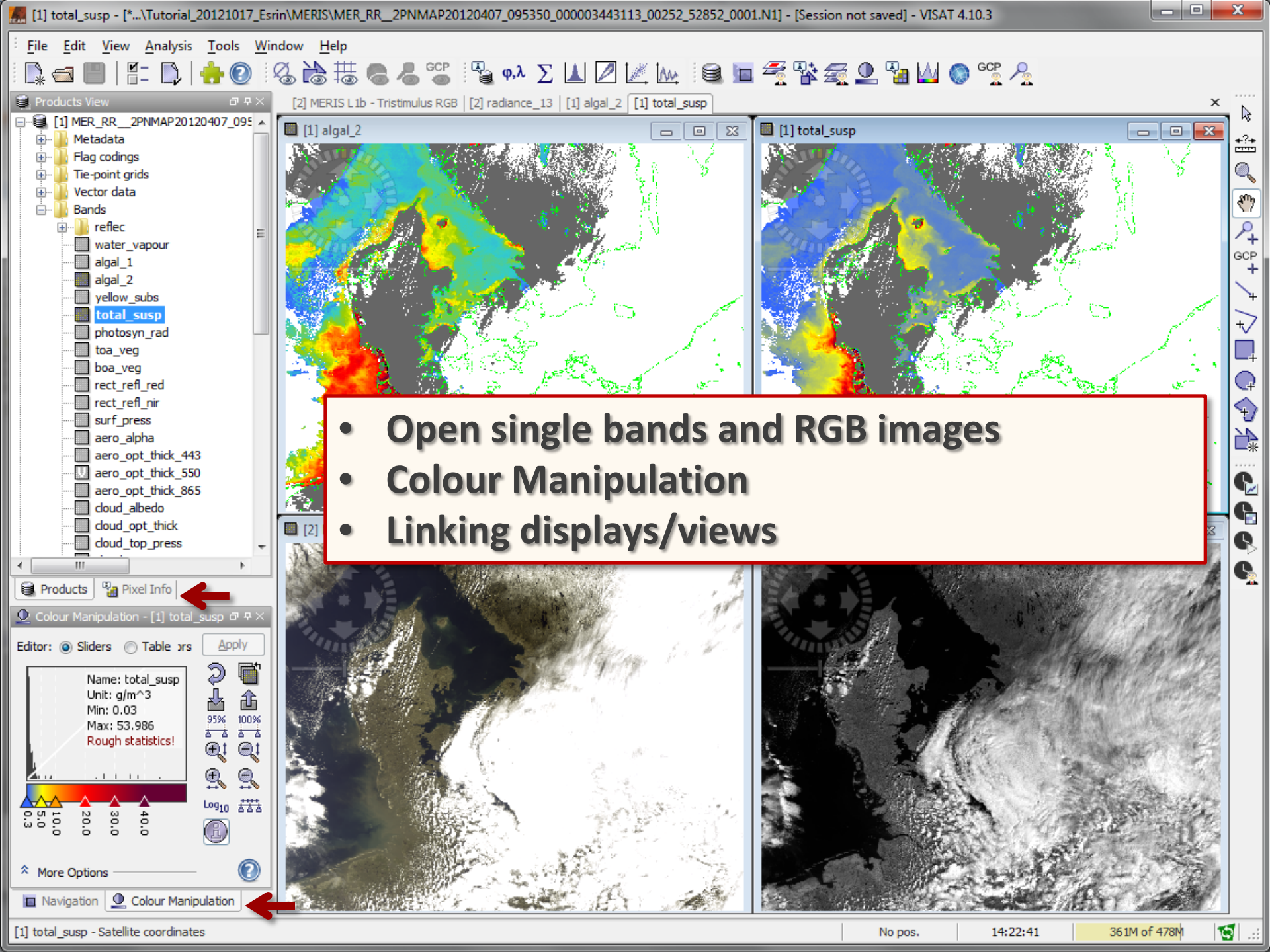


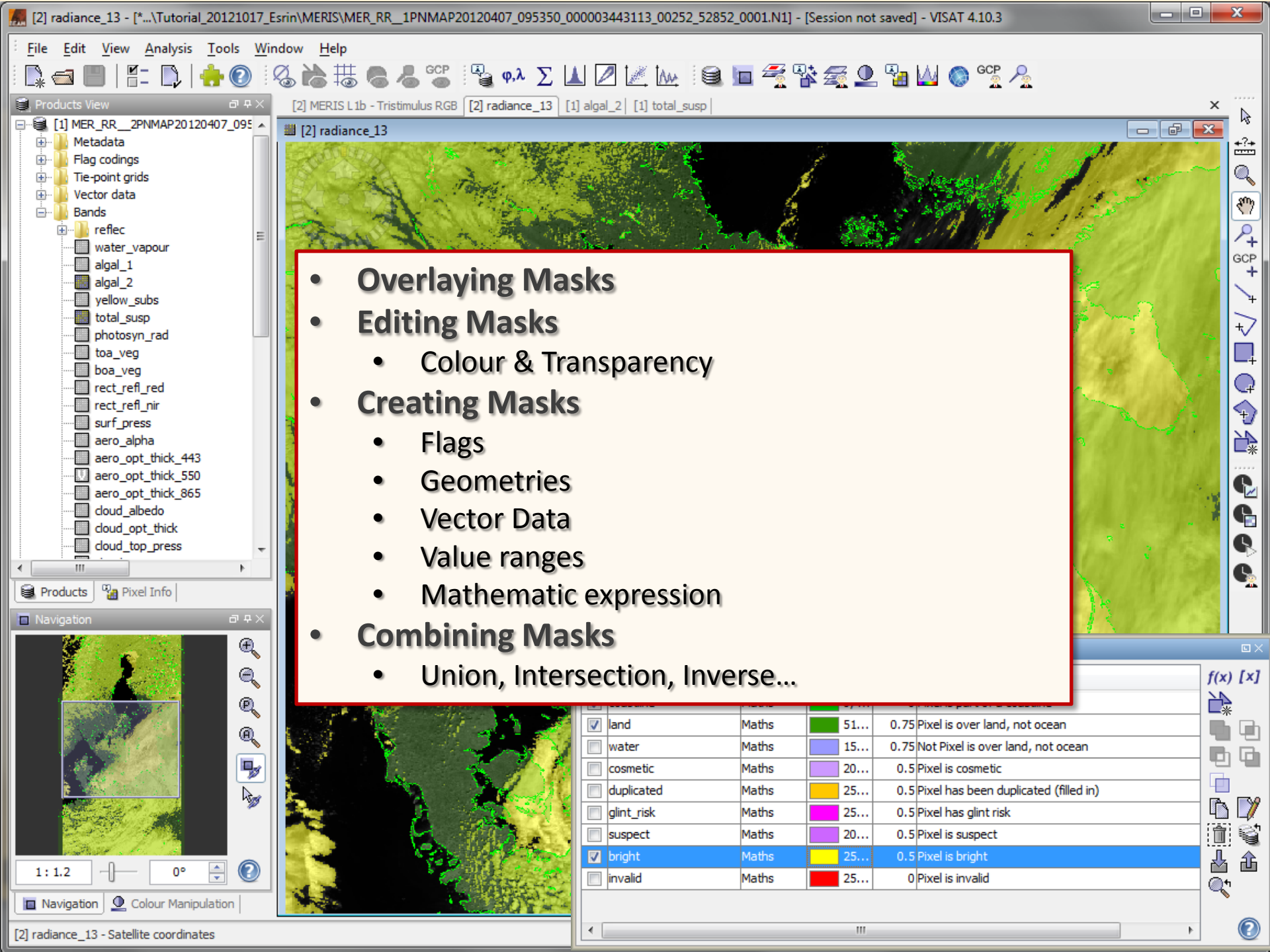
The Tools

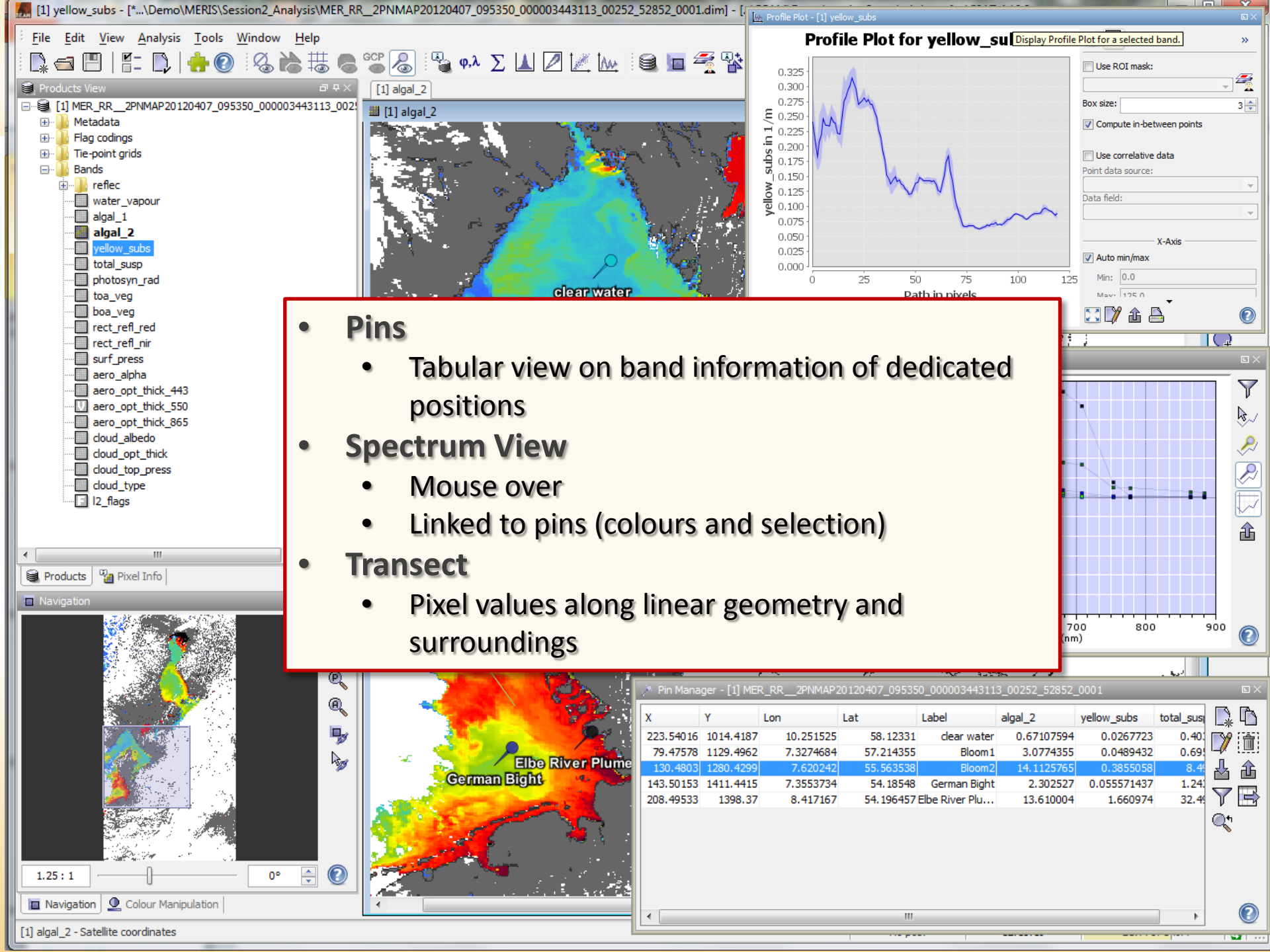
- Visualisation:
  - Very fast image display and navigation, RGB, colour bars, lots of layer types (masks, GIS layers), fast band arithmetics … >10 more
- Processing
  - Reprojections, GCP rectification, collocation, L3 binning, mosaicing, spectral unmixing, clustering, …
  - QAA IOP, NN-based AC, FLH-MCI, SST algorithms, and many 3rd party contributions, … >20 more
- Analysis:
  - Flexible mask & ROI management, ROI-based statistics,
  - Interactive scatter-, density-, profile-, histogram-plots,
  - Interactive spectra-, pixel-, flag-, time-series-views,
  - … >30 more

BEAM User Interfaces

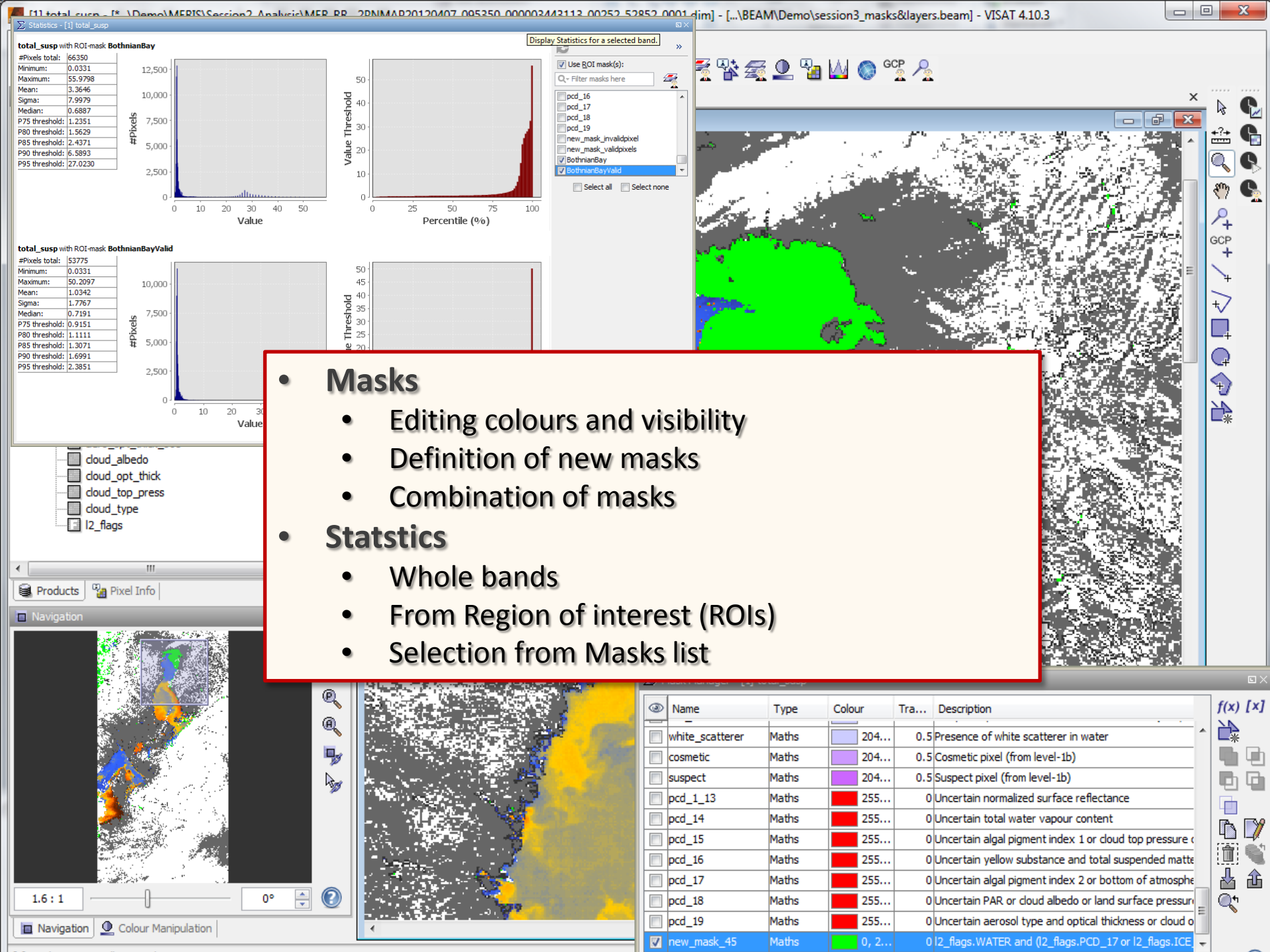
- VISAT: Graphical User Interface
- GPT: Command-line Interface
- API: Application Programming Interfaces
  - EO Data Model
  - EO Application Programming Interfaces
  - EO Rich Client Platform
  - EO Graph Processing Framework
  - Dynamic extensions via plug-in modules


[1] total_susp - [*...\Tutorial_20121017_Esrin\MERIS\MER_RR__2PNMAP20120407_095350_000003443113_00252_52852_0001.N1] - [Session not saved] - VISAT 4.10.3
File Edit View Analysis Tools Window Help
Products View
[1] MER_RR__2PNMAP20120407_095
Metadata
Flag codings
Tie-point grids
Vector data
Bands
reflec
water_vapour
algal_1
algal_2
yellow_subs
total_susp
photosyn_rad
toa_veg
boa_veg
rect_refl_red
rect_refl_nir
surf_press
aero_alpha
aero_opt_thick_443
aero_opt_thick_550
aero_opt_thick_865
cloud_albedo
cloud_opt_thick
cloud_top_press
Products
Pixel Info
Colour Manipulation - [1] total_susp
Editor: Sliders Table
Apply
Name: total_susp
Unit: g/m^3
Min: 0.03
Max: 53.986
Rough statistics!
0.3
5.0
10.0
20.0
30.0
40.0
95%
100%
Log10
More Options
Navigation
Colour Manipulation
[2] MERIS L1b - Tristimulus RGB
[2] radiance_13
[1] algal_2
[1] total_susp
[1] algal_2
[1] total_susp
[2]
• Open single bands and RGB images
• Colour Manipulation
• Linking displays/views
[1] total_susp - Satellite coordinates
No pos.
14:22:41
361M of 478M

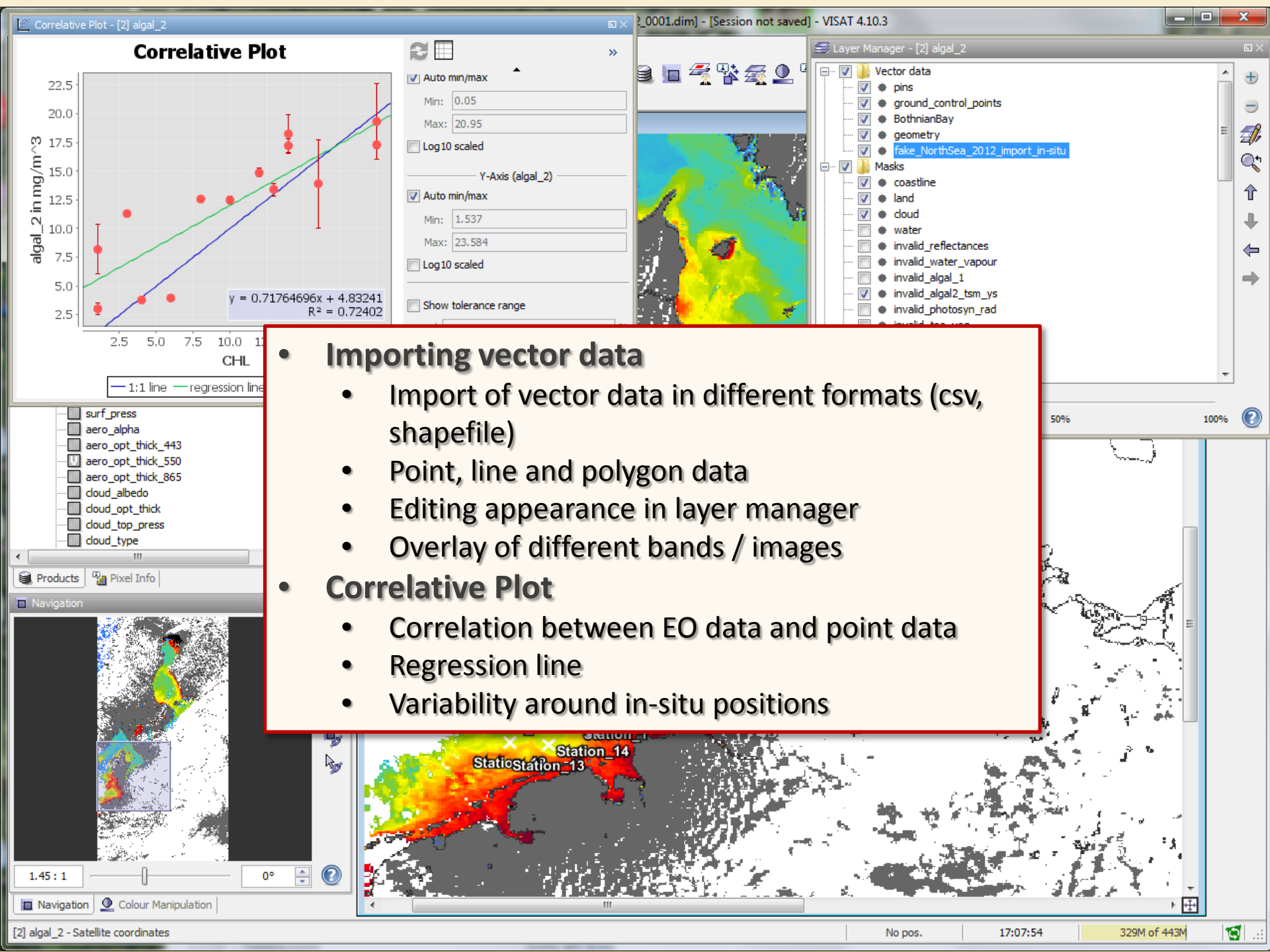

[2] radiance_13 - [*...\Tutorial_20121017_Esrin\MERIS\MER_RR__1PNMAP20120407_095350_000003443113_00252_52852_0001.N1] - [Session not saved] - VISAT 4.10.3
File Edit View Analysis Tools Window Help
Products View
[1] MER_RR__2PNMAP20120407_095
Metadata
Flag codings
Tie-point grids
Vector data
Bands
reflec
water_vapour
algal_1
algal_2
yellow_subs
total_susp
photosyn_rad
toa_veg
boa_veg
rect_refl_red
rect_refl_nir
surf_press
aero_alpha
aero_opt_thick_443
aero_opt_thick_550
aero_opt_thick_865
cloud_albedo
cloud_opt_thick
cloud_top_press
Products
Pixel Info
Navigation
1 : 1.2
0°
Navigation
Colour Manipulation
[2] MERIS L1b - Tristimulus RGB
[2] radiance_13
[1] algal_2
[1] total_susp
[2] radiance_13
• Overlaying Masks
• Editing Masks
• Colour & Transparency
• Creating Masks
• Flags
• Geometries
• Vector Data
• Value ranges
• Mathematic expression
• Combining Masks
• Union, Intersection, Inverse…
land Maths 51... 0.75 Pixel is over land, not ocean
water Maths 15... 0.75 Not Pixel is over land, not ocean
cosmetic Maths 20... 0.5 Pixel is cosmetic
duplicated Maths 25... 0.5 Pixel has been duplicated (filled in)
glint_risk Maths 25... 0.5 Pixel has glint risk
suspect Maths 20... 0.5 Pixel is suspect
bright Maths 25... 0.5 Pixel is bright
invalid Maths 25... 0 Pixel is invalid
[2] radiance_13 - Satellite coordinates



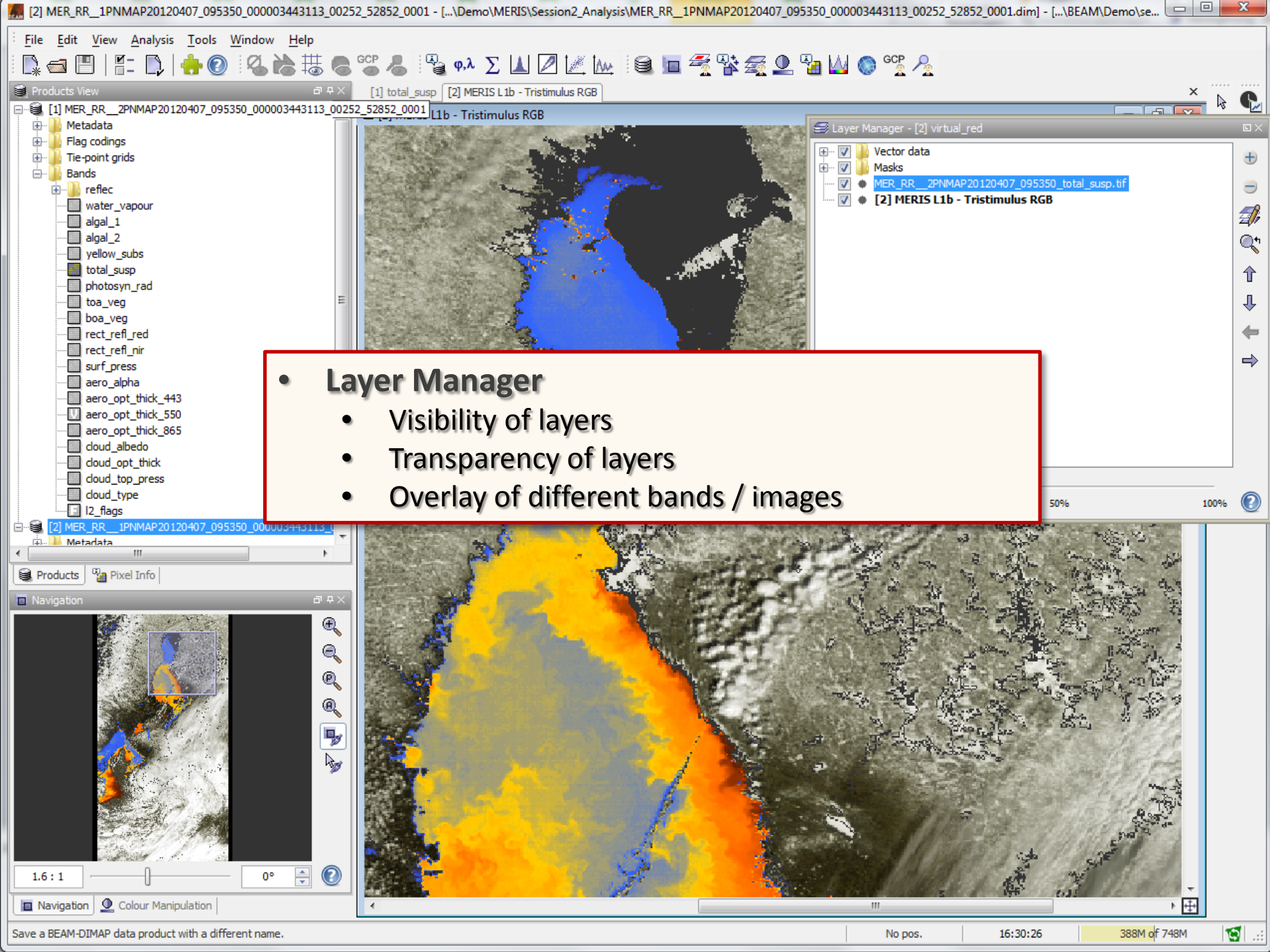
- **Pins**
  - Tabular view on band information of dedicated positions
- **Spectrum View**
  - Mouse over
  - Linked to pins (colours and selection)
- **Transect**
  - Pixel values along linear geometry and surroundings



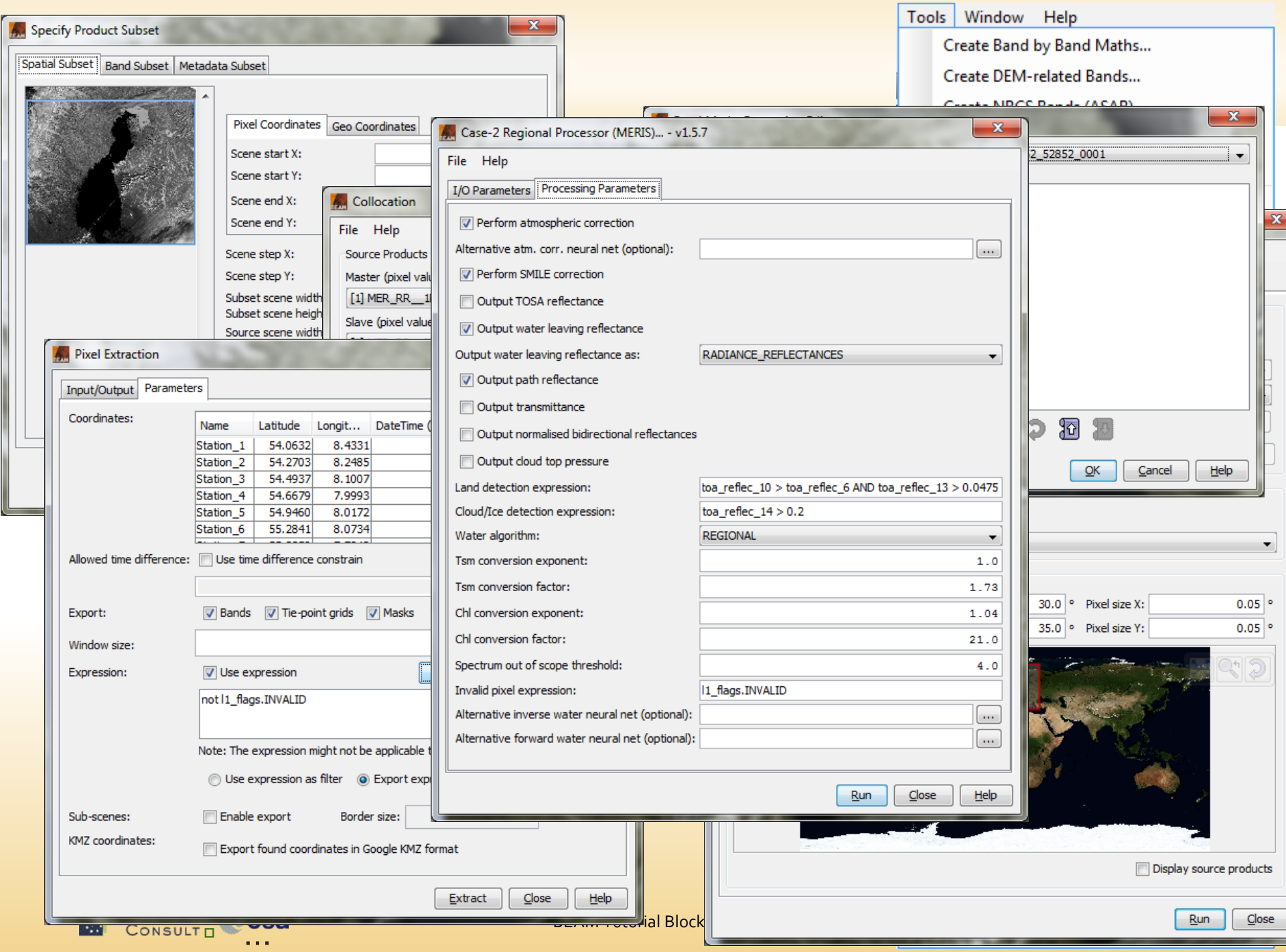
- **Masks**
  - Editing colours and visibility
  - Definition of new masks
  - Combination of masks
- **Statstics**
  - Whole bands
  - From Region of interest (ROIs)
  - Selection from Masks list

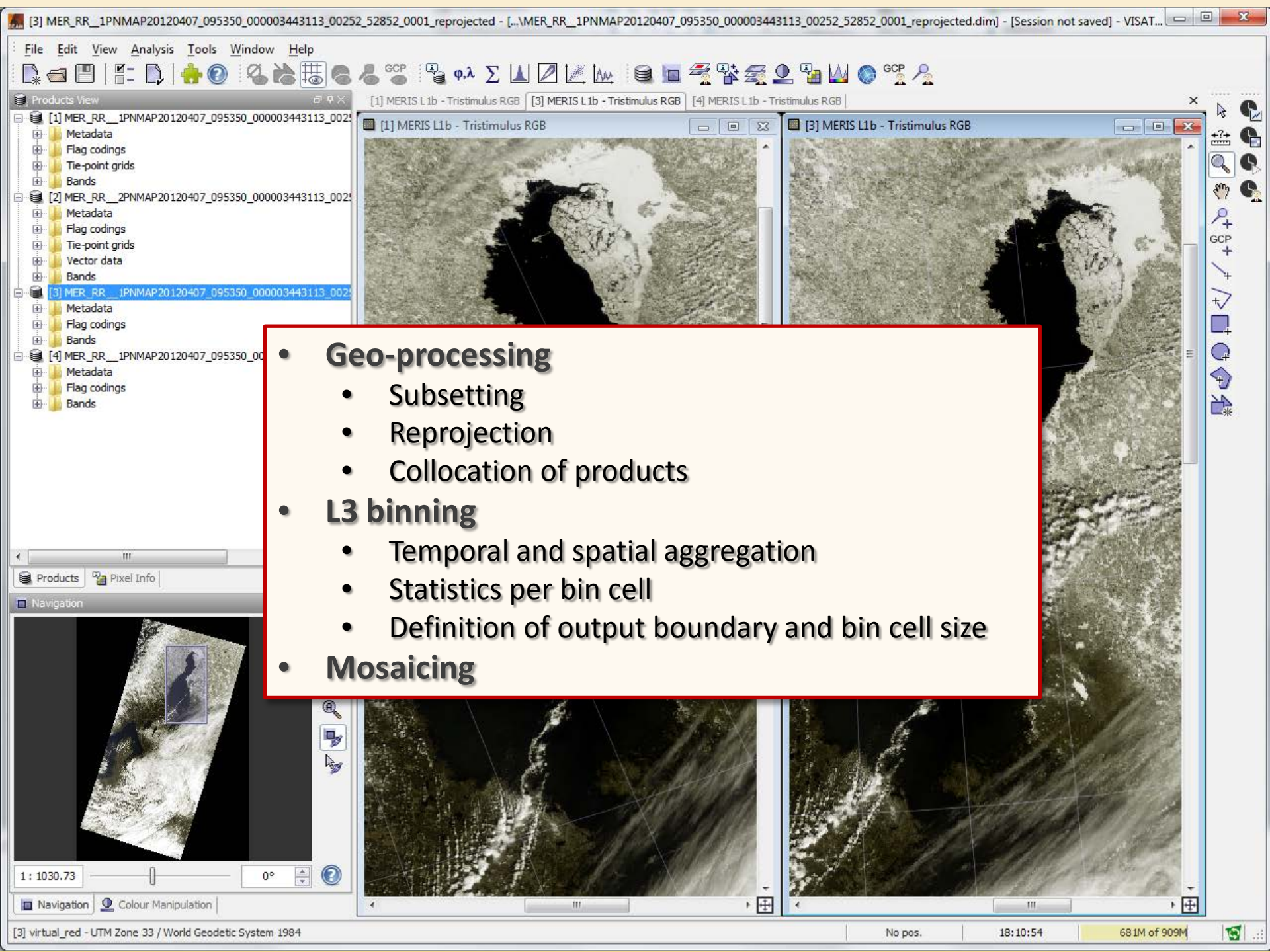


- **Importing vector data**
  - Import of vector data in different formats (csv, shapefile)
  - Point, line and polygon data
  - Editing appearance in layer manager
  - Overlay of different bands / images
- **Correlative Plot**
  - Correlation between EO data and point data
  - Regression line
  - Variability around in-situ positions

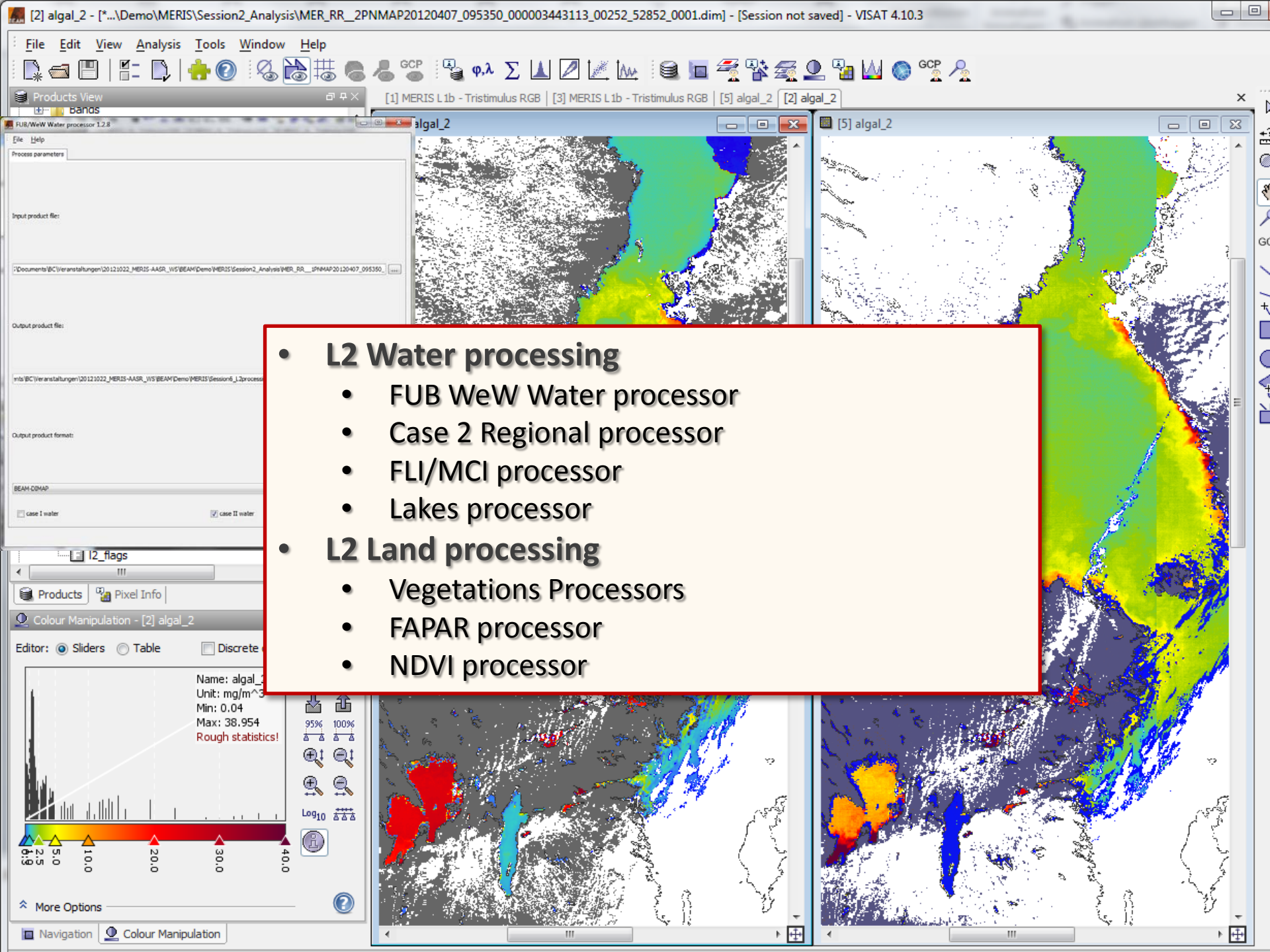


- **Layer Manager**
  - Visibility of layers
  - Transparency of layers
  - Overlay of different bands / images


Specify Product Subset
Spatial Subset
Band Subset
Metadata Subset
Pixel Coordinates
Geo Coordinates
Scene start X:
Scene start Y:
Scene end X:
Scene end Y:
Scene step X:
Scene step Y:
Subset scene width
Subset scene heigh
Source scene width
Collocation
File
Help
Source Products
Master (pixel valu
[1] MER_RR__1
Slave (pixel value
Pixel Extraction
Input/Output
Parameters
Coordinates:
Name
Latitude
Longit...
DateTime (
Station_1 54.0632 8.4331
Station_2 54.2703 8.2485
Station_3 54.4937 8.1007
Station_4 54.6679 7.9993
Station_5 54.9460 8.0172
Station_6 55.2841 8.0734
Allowed time difference:
Use time difference constrain
Export:
Bands
Tie-point grids
Masks
Window size:
Expression:
Use expression
not l1_flags.INVALID
Note: The expression might not be applicable t
Use expression as filter
Export exp
Sub-scenes:
Enable export
Border size:
KMZ coordinates:
Export found coordinates in Google KMZ format
Extract
Close
Help
Case-2 Regional Processor (MERIS)... - v1.5.7
File
Help
I/O Parameters
Processing Parameters
Perform atmospheric correction
Alternative atm. corr. neural net (optional):
Perform SMILE correction
Output TOSA reflectance
Output water leaving reflectance
Output water leaving reflectance as:
RADIANCE_REFLECTANCES
Output path reflectance
Output transmittance
Output normalised bidirectional reflectances
Output cloud top pressure
Land detection expression:
toa_reflec_10 > toa_reflec_6 AND toa_reflec_13 > 0.0475
Cloud/Ice detection expression:
toa_reflec_14 > 0.2
Water algorithm:
REGIONAL
Tsm conversion exponent:
1.0
Tsm conversion factor:
1.73
Chl conversion exponent:
1.04
Chl conversion factor:
21.0
Spectrum out of scope threshold:
4.0
Invalid pixel expression:
l1_flags.INVALID
Alternative inverse water neural net (optional):
Alternative forward water neural net (optional):
Run
Close
Help
Tools
Window
Help
Create Band by Band Maths...
Create DEM-related Bands...
2_52852_0001
OK
Cancel
Help
30.0
Pixel size X:
0.05
35.0
Pixel size Y:
0.05
Display source products
Run
Close

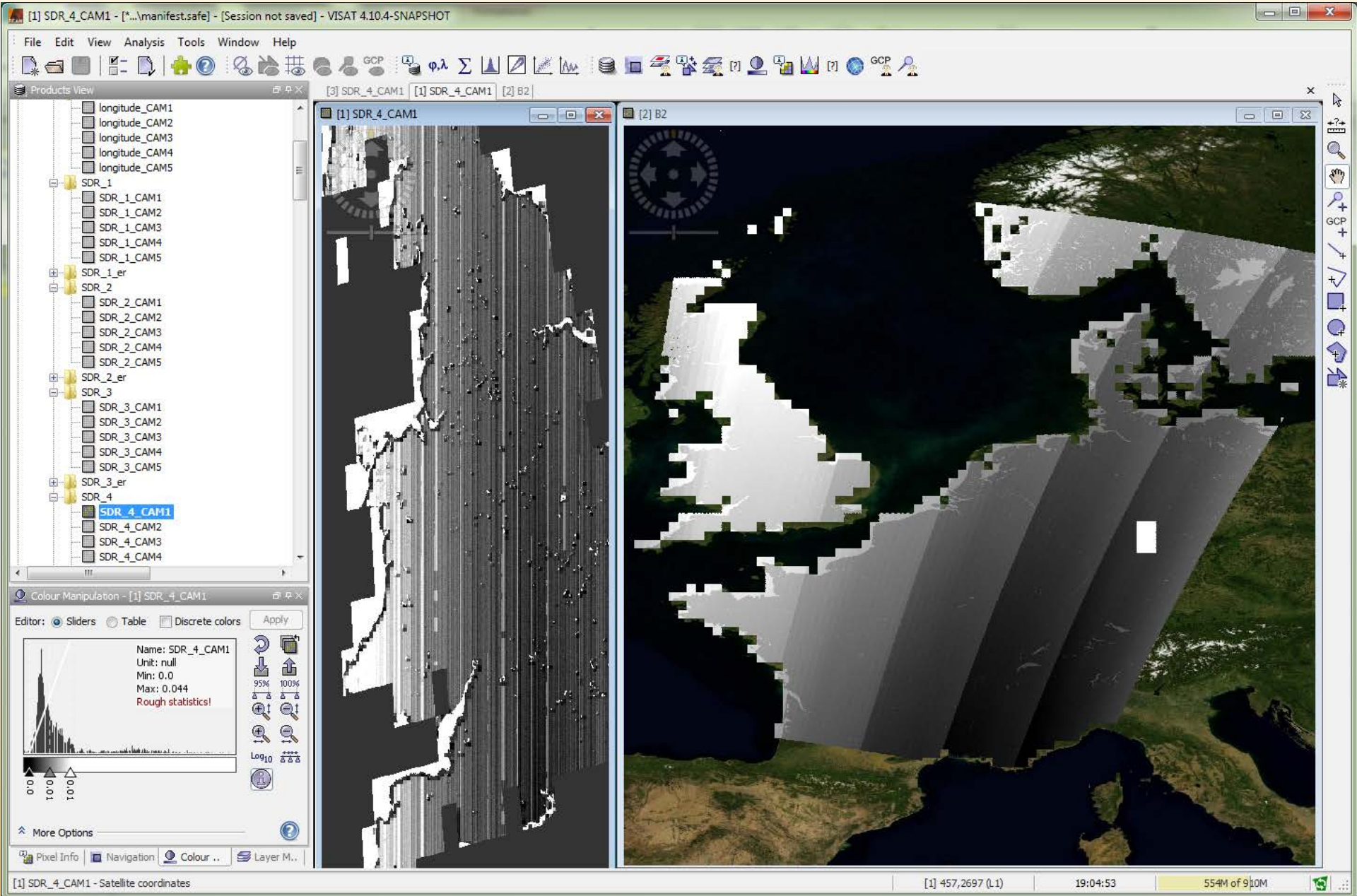


- **Geo-processing**
  - Subsetting
  - Reprojection
  - Collocation of products
- **L3 binning**
  - Temporal and spatial aggregation
  - Statistics per bin cell
  - Definition of output boundary and bin cell size
- **Mosaicing**



- **L2 Water processing**
  - FUB WeW Water processor
  - Case 2 Regional processor
  - FLI/MCI processor
  - Lakes processor
- **L2 Land processing**
  - Vegetations Processors
  - FAPAR processor
  - NDVI processor

Sentinel-3 Reader available



Command-Line Interface - GPT

BEAM Command Line

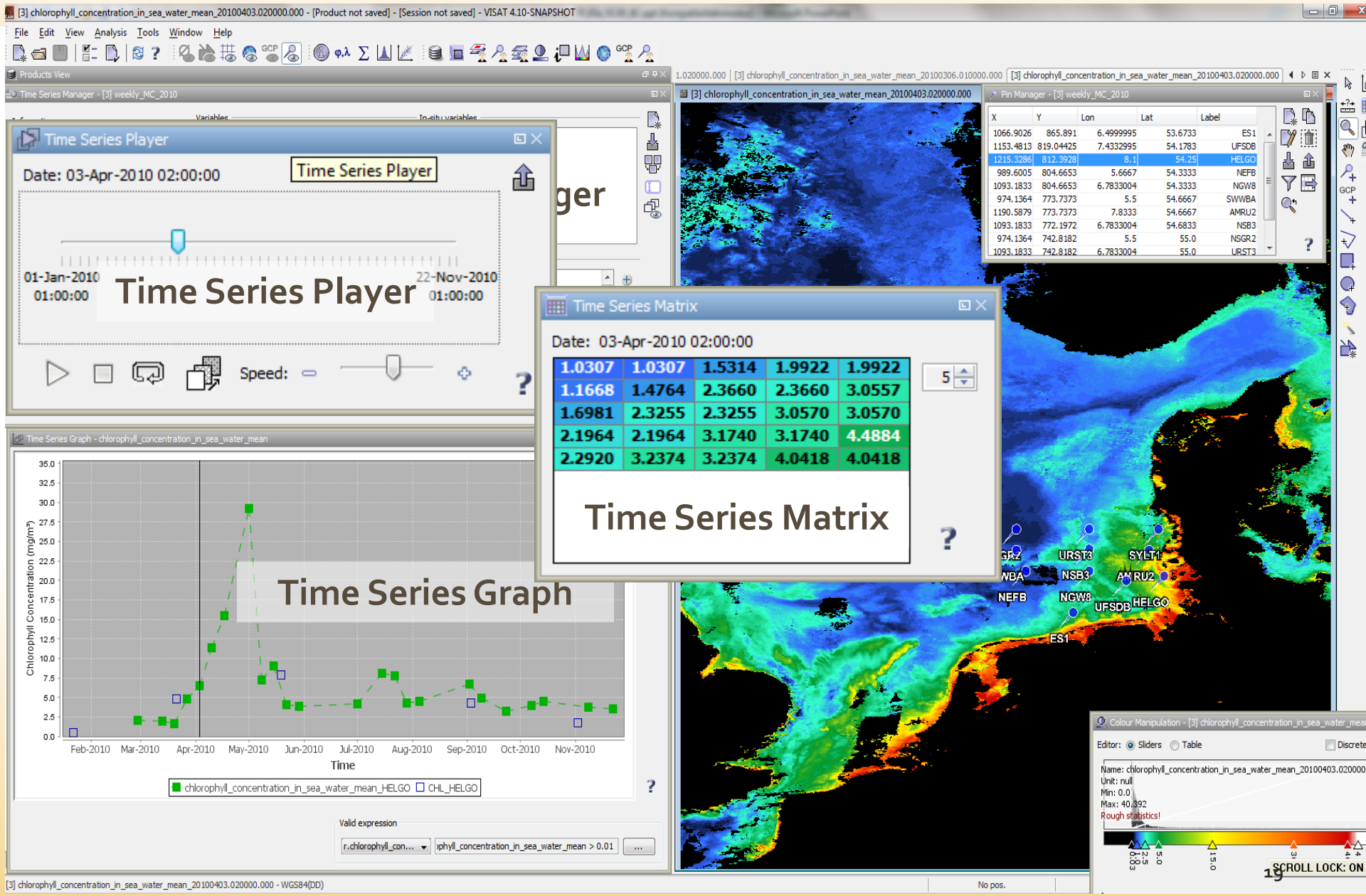
```
  -T<target>=<file>  Defines a target product. Valid for graphs only. <target>
                     must be the identifier of a node in the graph. The node's
                     output will be written to <file>.
  -S<source>=<file>  Defines a source product. <source> is specified by the
                     operator or the graph. In an XML graph, all occurrences of
                     ${<source>} will be replaced with references to a source
                     product located at <file>.
  -P<name>=<value>   Defines a processing parameter, <name> is specific for the
                     used operator or graph. In an XML graph, all occurrences of
                     ${<name>} will be replaced with <value>. Overwrites
                     parameter values specified by the '-p' option.

Operators:
  Aatsr.SST                 Computes sea surface temperature (SST) from (A)ATSR products.
  BandMaths                 Create a product with one or more bands using mathematical expressions.
  Binning                   Performs spatial and temporal aggregation of pixel values into 'bin' cells
  Collocate                 Collocates two products based on their geo-codings.
  EMClusterAnalysis         Performs an expectation-maximization (EM) cluster analysis.
  FlhMci                    Computes fluorescence line height (FLH) or maximum chlorophyll index (MCI).
  KMeansClusterAnalysis     Performs a K-Means cluster analysis.
  Merge                     Allows copying raster data from any number of source products to a specified
ct.
  Meris.Brr                 Compute the BRR of a MERIS L1b product.
  Meris.Case2Regional       Performs IOP retrieval on L1b MERIS products, including atmospheric correctio
  Meris.CorrectRadiometry   Performs radiometric corrections on MERIS L1b data products.
  Meris.GlintCorrection     MERIS atmospheric correction using a neural net.
  Meris.Lakes               Performs IOP retrieval for eutrophic and boreal Lakes on L1b MERIS products,
spheric correction.
  Meris.N1Patcher           Copies an existing N1 file and replaces the data for the radiance bands
  Mosaic                    Creates a mosaic out of a set of source products.
  PixEx                     Extracts pixels from given locations and source products.
  Read                      Reads a product from disk.
  Reproject                 Reprojection of a source product to a target Coordinate Reference System.
  Subset                    Create a spatial and/or spectral subset of a data product.
  Unmix                     Performs a linear spectral unmixing.
  Write                     Writes a data product to a file.
  glint.Flint               Flint Processor.
```

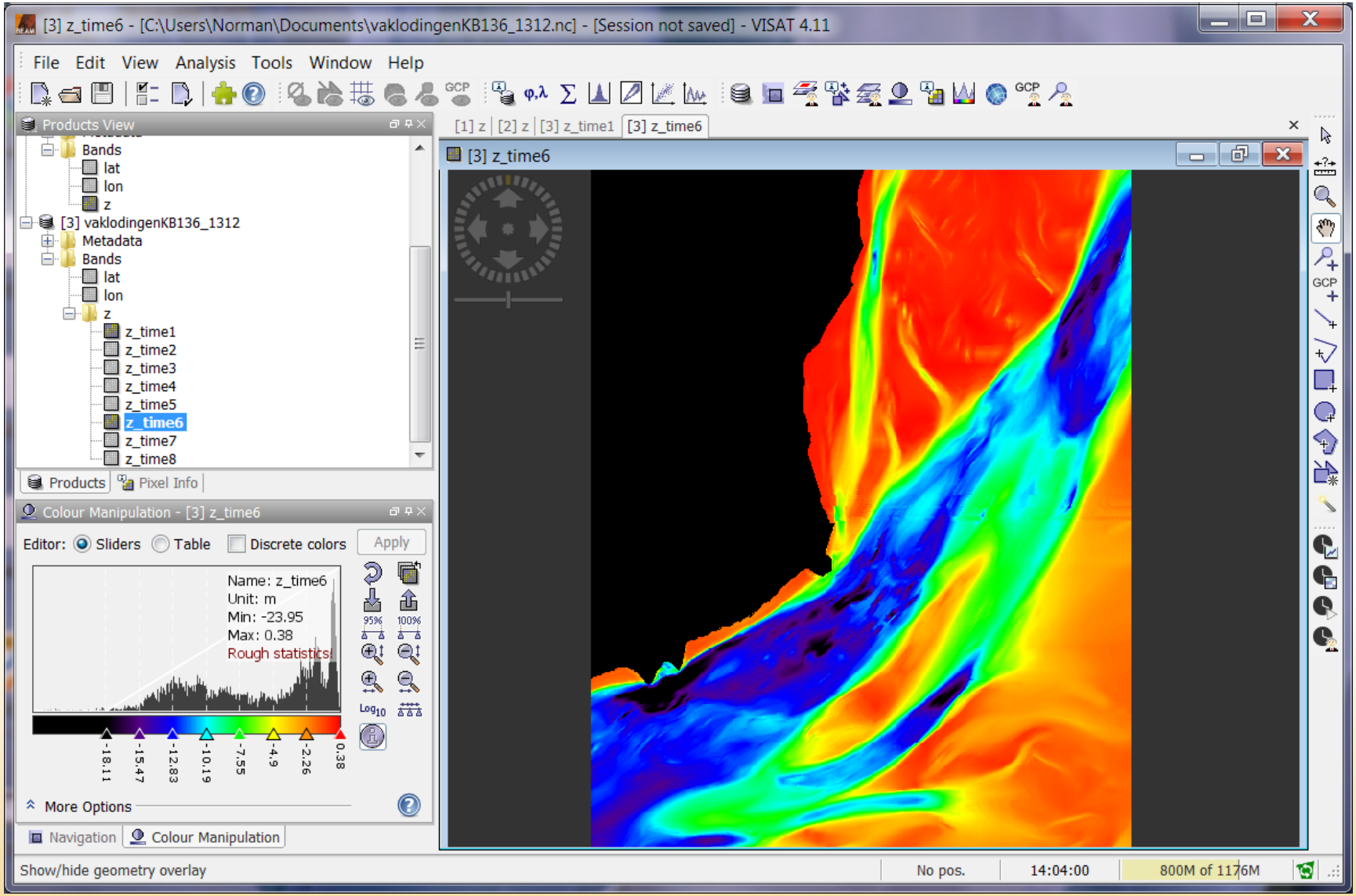
BEAM 4.11

- Released in April 2013
- New Features
  - Interactive Time Series Tools
  - OPeNDAP Access
  - Temporal percentile and gap-filling operator
  - New, faster and more flexible Level-3 binning
  - NetCDF 4 output format
  - All SeaDAS / OBPG input formats (MODIS, SeaWiFS, VIIRS, OCS, etc.)
- Fixes and optimisations

Time Series Tools



OPeNDAP Access



BEAM 5 Plans

- Prototype reader modules for
  - Sentinel-3 OLCI and SLSTR
  - Sentinel-2 MSI, ATCOR Integration
  - (Sentinel-1 SAR through NEST)
- C and Python API
  - Embedding BEAM: Scripting, batch mode processing
  - Extending BEAM: Tools and processors
- "Backport" SeaDAS extensions into BEAM
- Release in Fall 2013

Sentinel-3 and -2 Support in BEAM

- Sentinel-3 Products
  - OLCI L1
  - OLCI Water L2
  - OLCI Land L2
  - SLSTR L1
  - SLSTR Water L2
  - SLSTR Land L2
  - SYN L2
  - VEG L2
- Sentinel-2 Products
  - MSI L1C
  - MSI L2A

- Applicable tools in BEAM
  - Image analysis
  - Layer management
  - Flag overlay
  - Mask management
  - Spectrum view
  - Spectral unmixing
  - Band arithmetic
  - Geo-corrections / -projections
  - Transect profiles
  - Region of interest statistics
  - Time series analysis
  - Mosaicking
  - Level-3 binning

SeaDAS 7.0

Staff:

Aynur Abdurazik

Sean Bailey

Matt Elliott

Danny Knowles

Don Shea

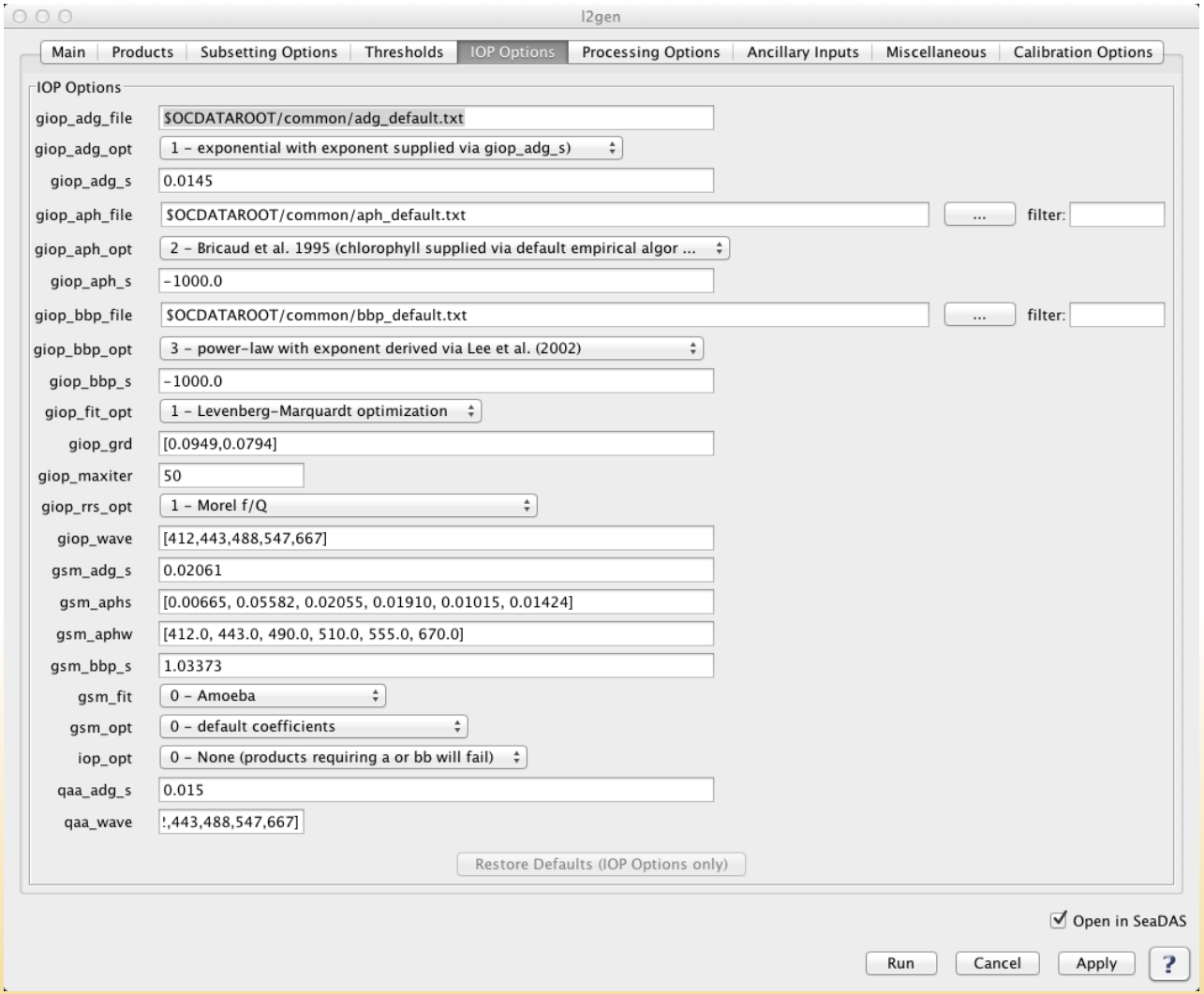
SeaDAS 7.0

- Objective
  - Renewal of the „outdated" SeaDAS 6 user interface
  - Away from commercial IDL to an open-source approach
  - Simplify configuration and launching of SeaDAS L[01] - L3 data processors
- Collaboration
  - Joint effort of NASA Ocean Biology Processing Group (OBPG) and the BEAM development team
  - Informal meeting at NASA GSFC in May, 2010
    → Decided that *SeaDAS 7 would use the BEAM Development Platform*
  - Bilateral collaboration started in June, 2011
  - Beta Release in June 2012, Final Release April 2013

SeaDAS 7.0 Features

- Exchange of the IDL-based SeaDAS GUI by a frontend based on BEAM **VISAT** "Rich Client Platform"
- Add BEAM support for OPBP maintained data products
  - Aquarius, CZCS, HICO, MERIS, MODIS, MOS, OCM, OCTS, SeaWiFS, VIIRS
- Integrate SeaDAS' robust and fast **data processing suite**
  - NASA operational OC processors used for production
  - greatly simplified usage of SeaDAS data processors (e.g. **l1bgen**, **l2gen**, l2bin, etc.
  - sensor-independent approach
  - data processor user interfaces dynamically created from XML files
    - created by the processing programs.
    - Modifying the programs automatically modifies the
  - Linux and MacOSX only, use virtual machine on Windows platforms

L2gen SeaDAS 7.0



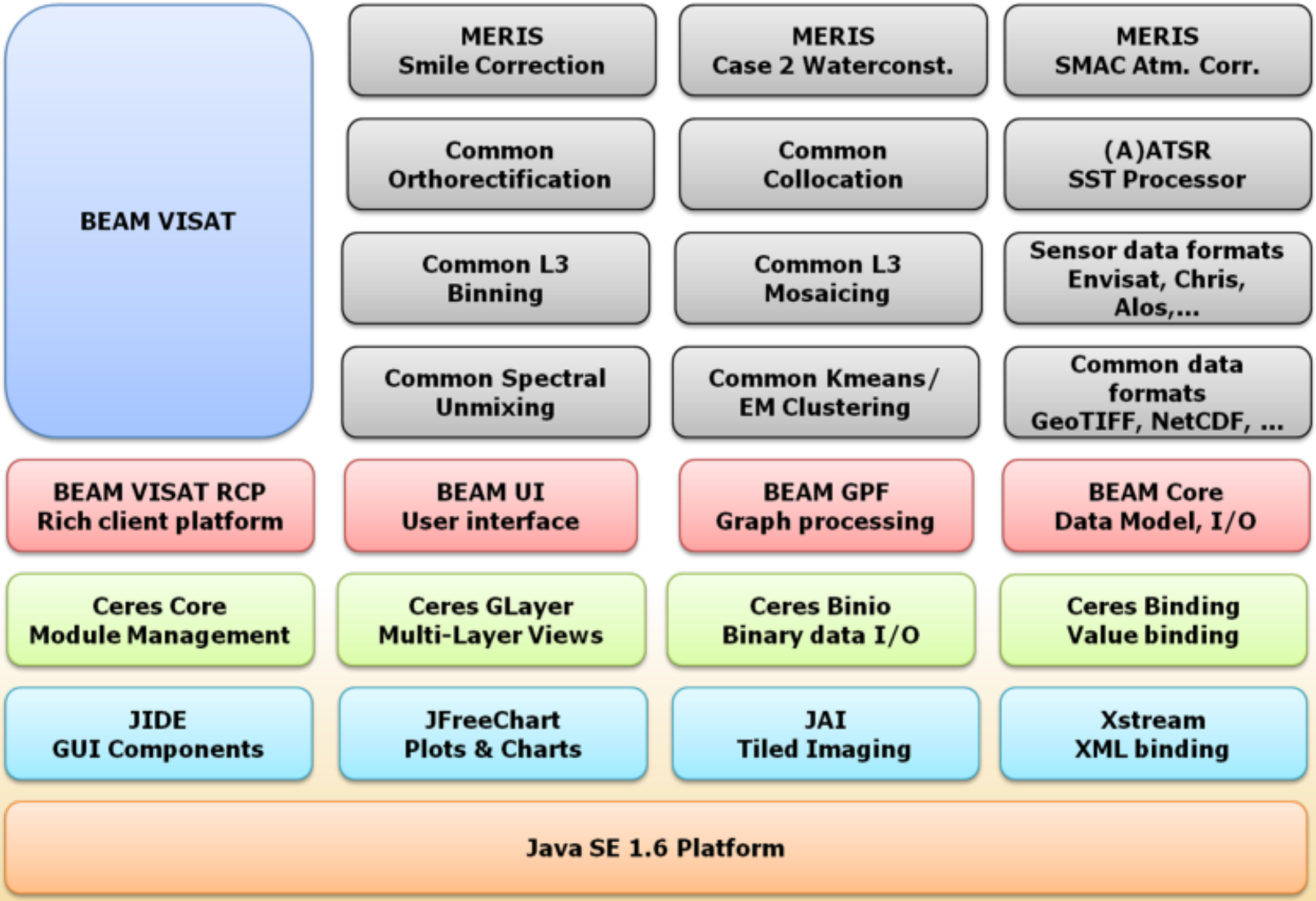
SeaDAS 7.0 Objectives (cont.)

- Improve SeaDAS/BEAM w.r.t. **validation activities**
- Improvements to the SeaDAS/BEAM **point and vector data** support (e.g. support for SeaBASS-formatted files)
- Added a global, high resolution **land-water mask**
- Will add a global, accurate **bathymetry map**
- Added **auxiliary data management** (e.g., download, …)
- Added a simplified interface to the Color Manipulation Tool
- Odds and ends
  - Add a layer for legends in image views
  - Extend processing capabilities to Windows operating system
  - Add additional user-defined preferences
  - Color manipulation tool preferences
  - Processing option preferences

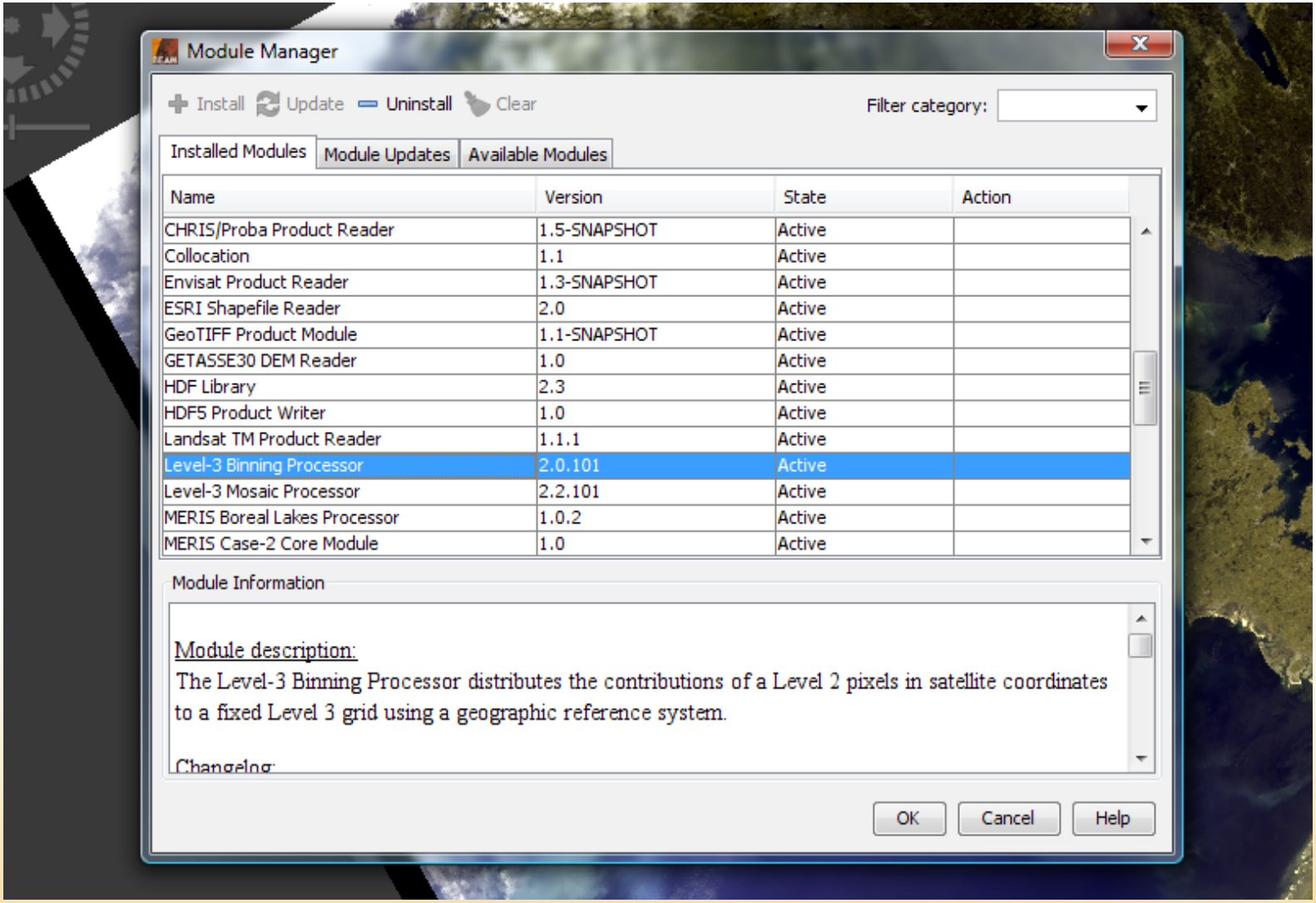
Thanks for your attention!

→ Don't forget: You get instant support in the BEAM and SeaDAS user forums.

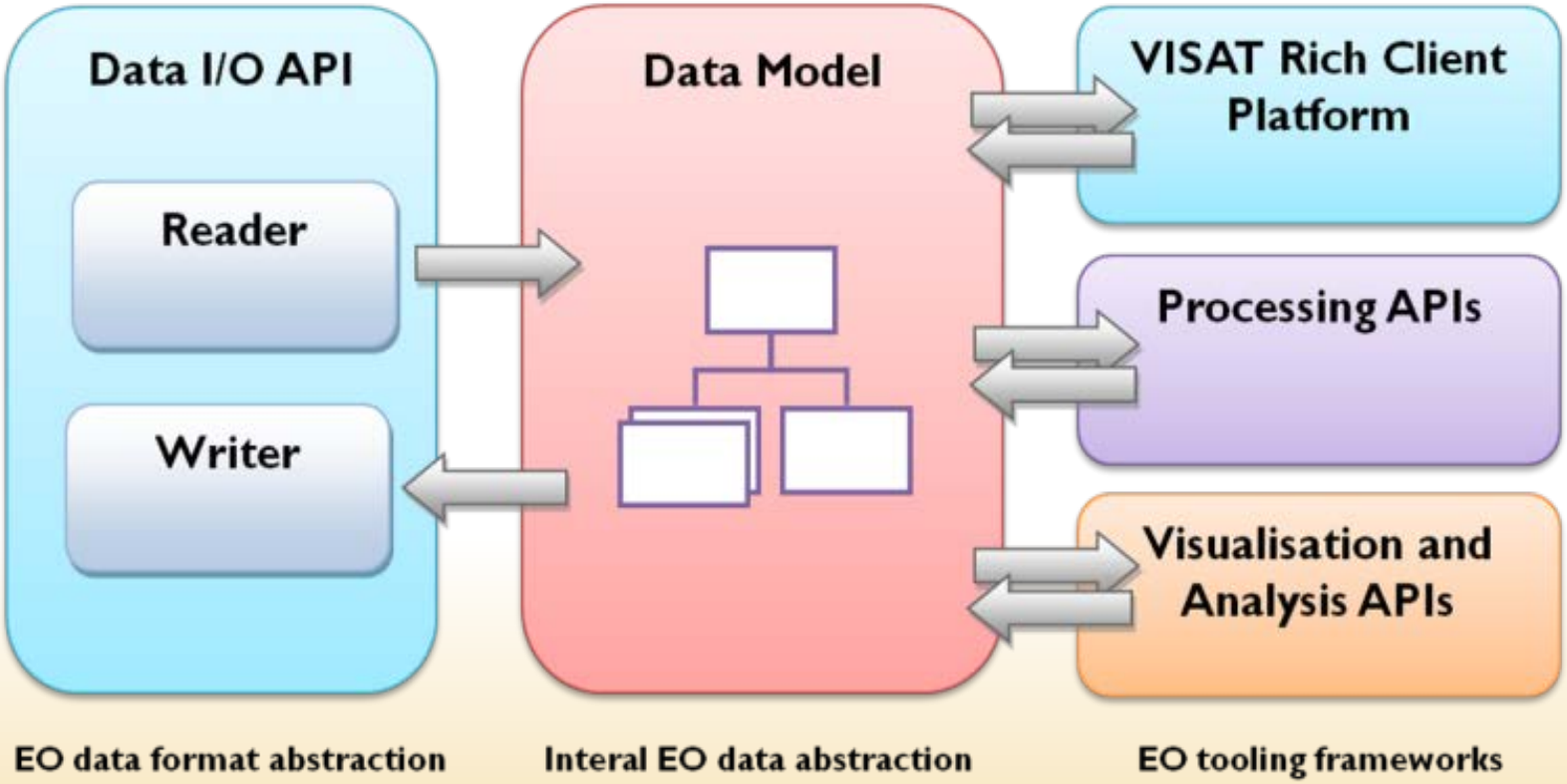
Architecture Overview



VISAT Module Manager

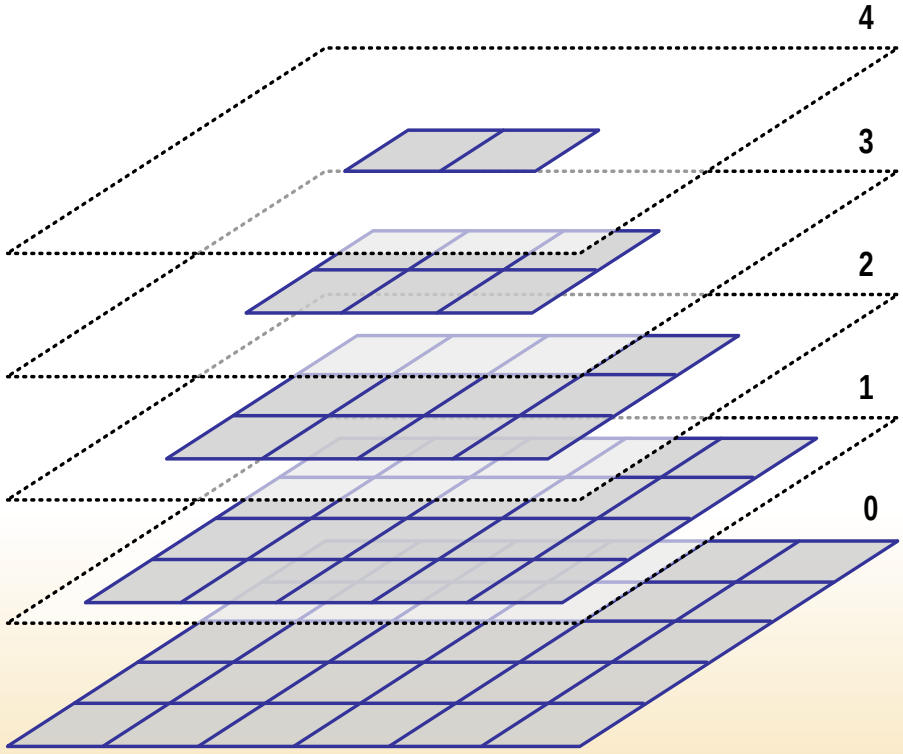


Generic EO Data Model

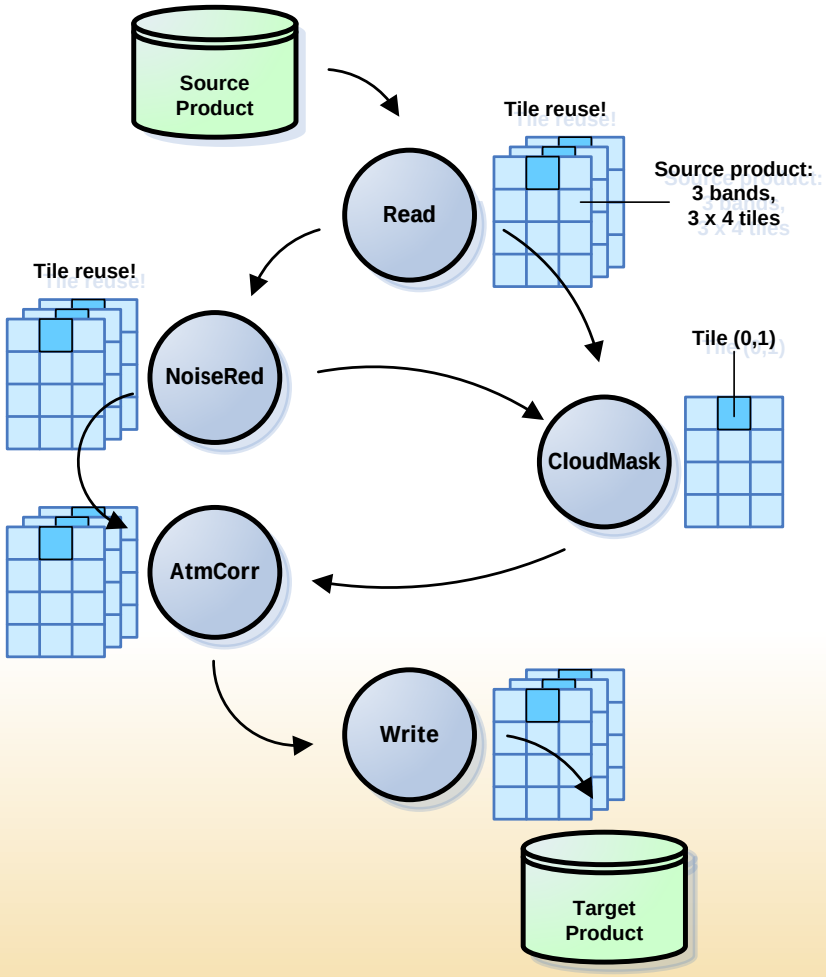


Raster Data Management

- Tiled images
- Multi-resolution image pyramids
- Multi-threaded tile processing
- Loading visible tiles, caching invisible
- Allows browsing giga-pixel images



Graph Processing Framework



- Inversion of execution flow, “pull” processing
- Requests are propagated from sink to source: only requested data is processed
- Independent tile computation is parallelised, multi-threading
- Intermediate results are kept in-memory, no I/O overhead

BEAM Success Factors

- Abstraction of EO data products:
  - Generic Product Model (internal representation)
- Abstraction of data input, output, processors
  - Readers, Writers, Operators
- Module-based architecture
  - Every module is a versioned, exchangeable plugin
- Tile-based raster data management
  - Image display
  - Data processing

Python FLH "Processor"

```
reflProduct =    \
ProductIO.readProduct(sys.argv[1])


b1 = reflProduct.getBand('reflec_5')
b2 = reflProduct.getBand('reflec_7')
b3 = reflProduct.getBand('reflec_9')


w1 = b1.getSpectralWavelength()
w2 = b2.getSpectralWavelength()
w3 = b3.getSpectralWavelength()


a = (w2 - w1) / (w3 - w1)

k = 1.03


…
```

```
flhProduct = Product.newProduct('FLH.nc', 'test',
width, height)

flhBand = flhProduct.addNewBand('FLH',
ProductData.TYPE_FLOAT32)


…


for y in range(height):

    b1.readPixelsFloat(0, y, width, 1, r1)
    b2.readPixelsFloat(0, y, width, 1, r2)
    b2.readPixelsFloat(0, y, width, 1, r3)

    print("processing line ", y, " of ", height)

    FLH = r2 – k * (r1 + a * (r3 – r1))

    flhBand.writePixelsFloat(0, y, width, 1, FLH)
```