

Sean Bailey – NASA GSFC
Norman Fomferra – Brockmann Consult

SeaDAS and BEAM User Tools

Data Processing, Analysis and Exploitation Tools



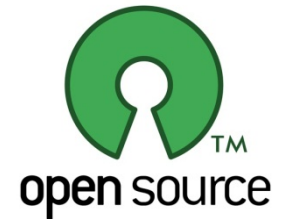
International Ocean Colour Science

Meeting 2013

Darmstadt, 07.05.2013

The **BEAM** Project

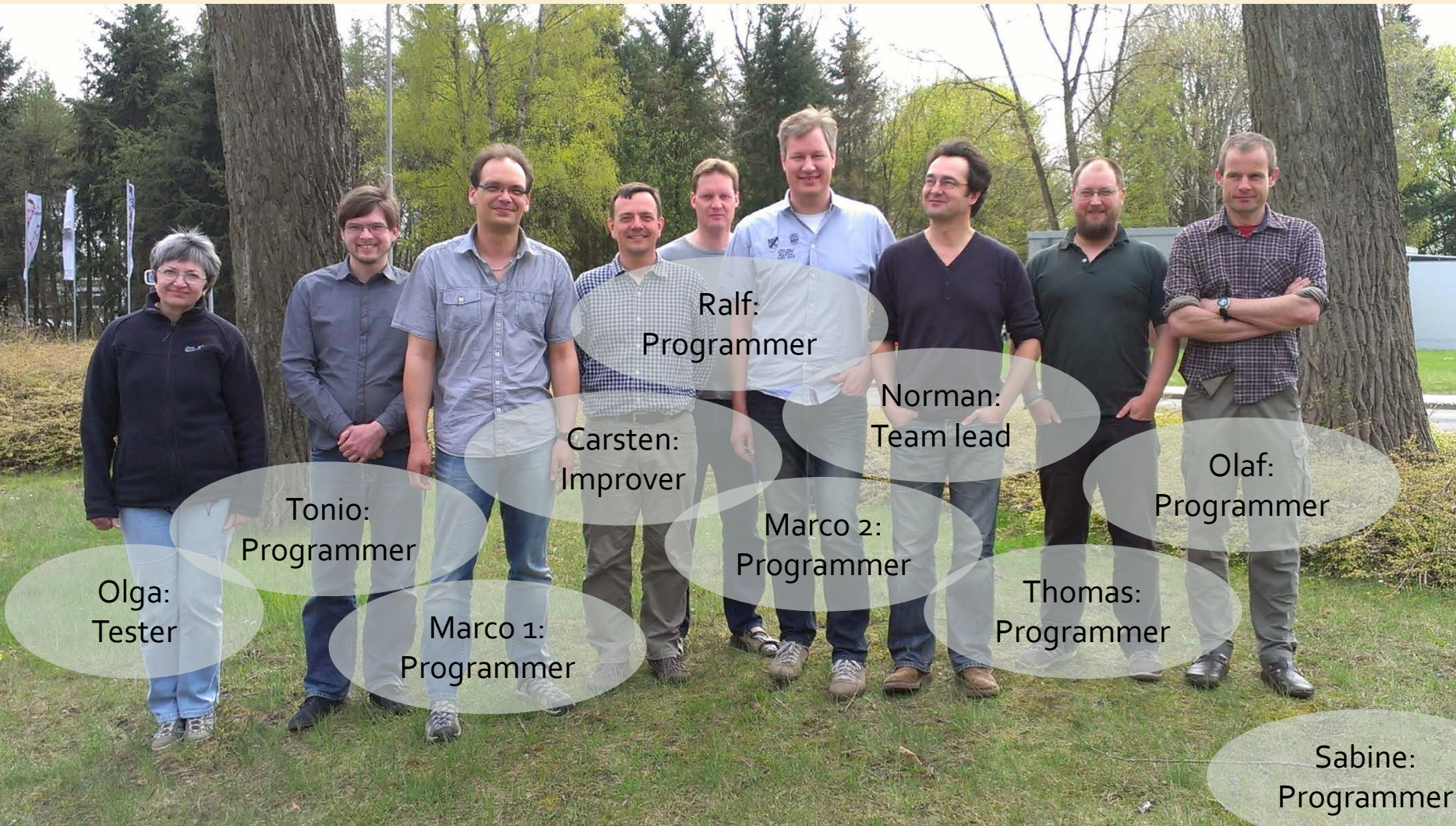
- ESA project kicked off for exploitation of **Envisat** data
- Open source, agile software development
- Platform neutral, 100% Java
- BEAM today
 - 24 public releases, hundreds of module updates
 - Thousands of users worldwide
 - Dozens of projects use and support it (ESA, EU, EUMETSAT, NASA)
 - Dozens 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

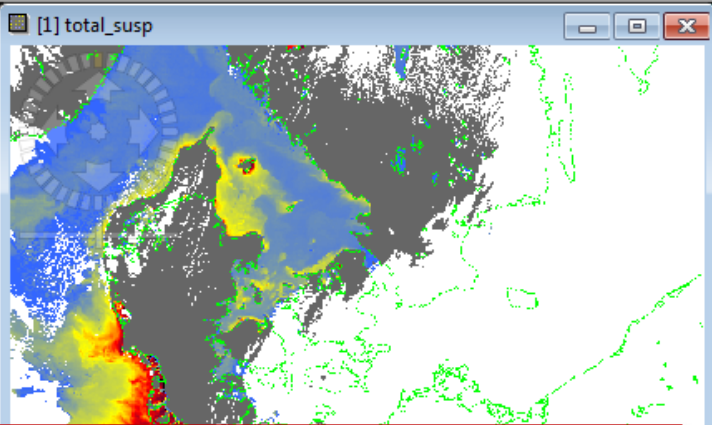
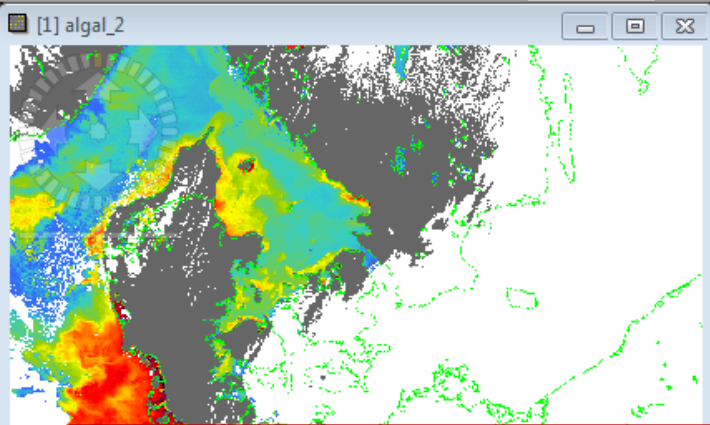
- Visualisation:
 - Very fast image display and navigation, RGB, colour bars, lots of layer types (masks, GIS layers), fast band arithmetics ... >10 more
- Processing
 - Reprojections, GCP rectification, collocation, L3 binning, mosaicing, spectral unmixing, clustering, ...
 - QAA IOP, NN-based AC, FLH-MCI, 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

Products View

- [1] MER_RR_2PNMAP20120407_095350
 - 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



- Open single bands and RGB images
- Colour Manipulation
- Linking displays/views

Products Pixel Info

Colour Manipulation - [1] total_susp

Editor: Sliders Table rs

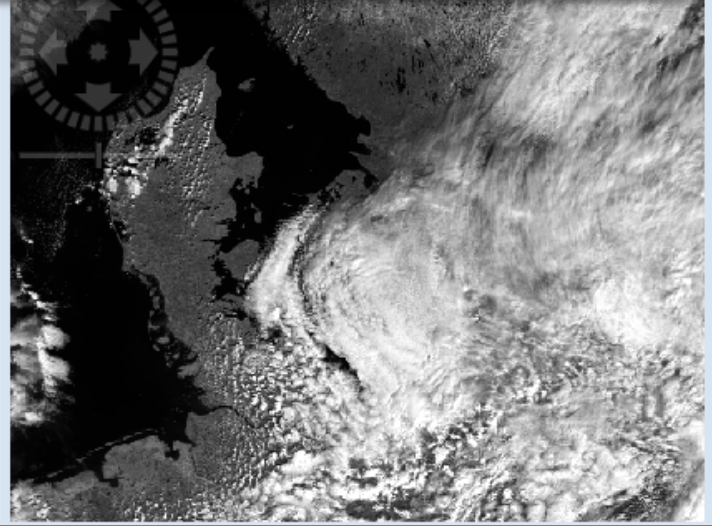
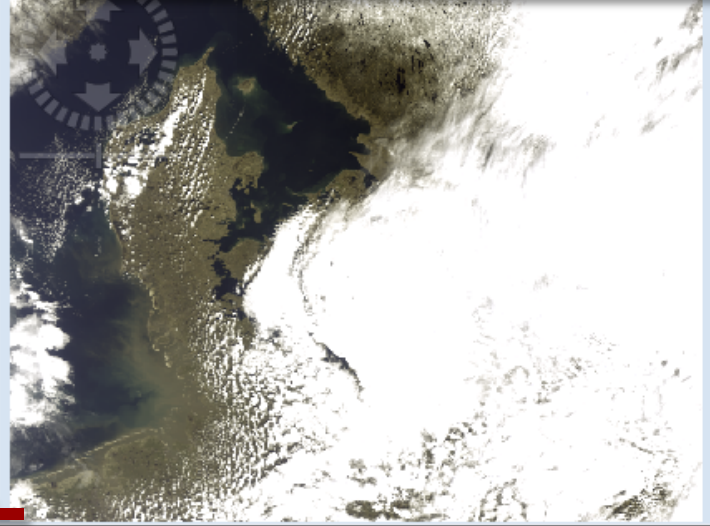
Name: total_susp
Unit: g/m³
Min: 0.03
Max: 53.986
Rough statistics!

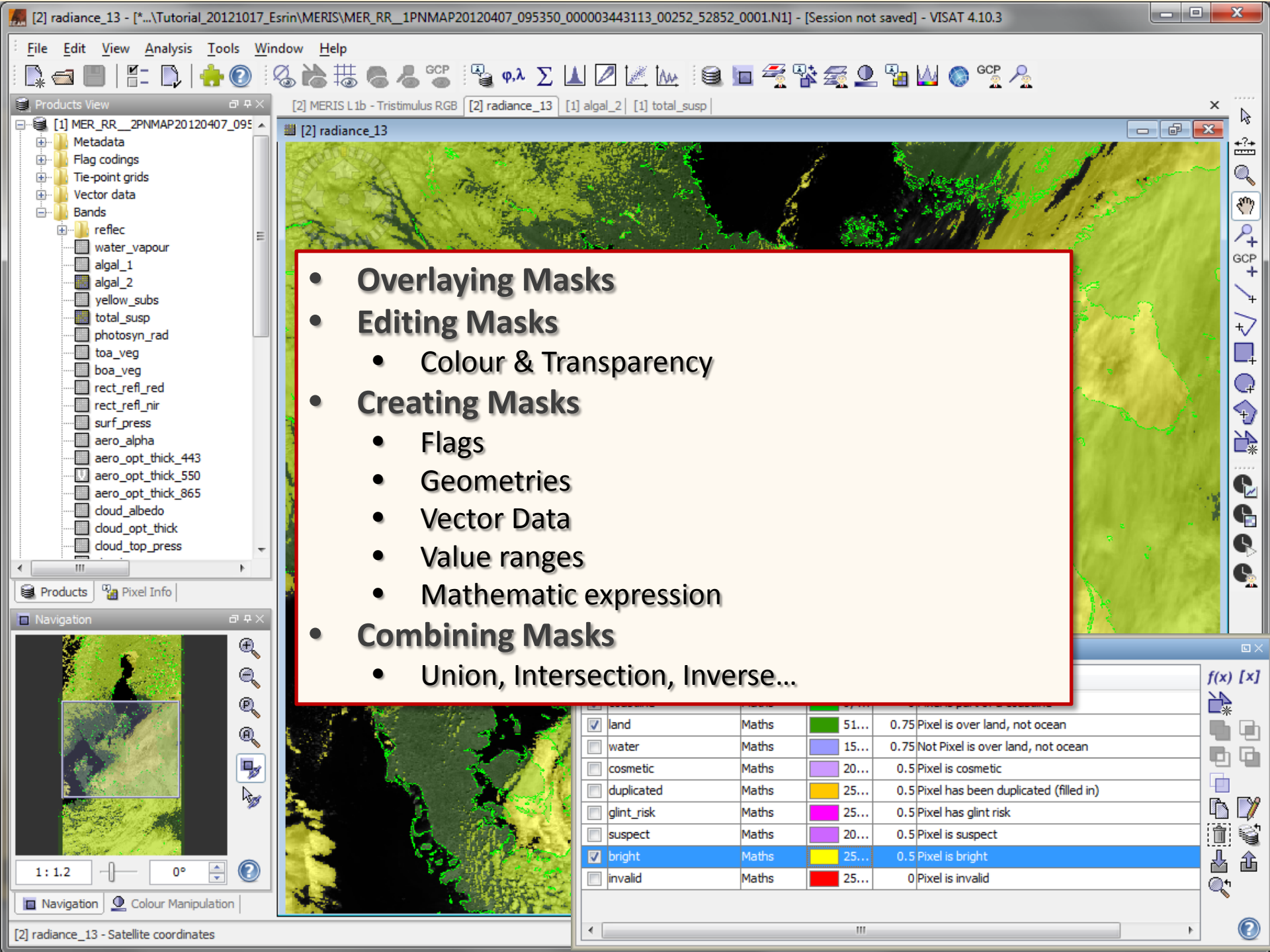
95% 100%

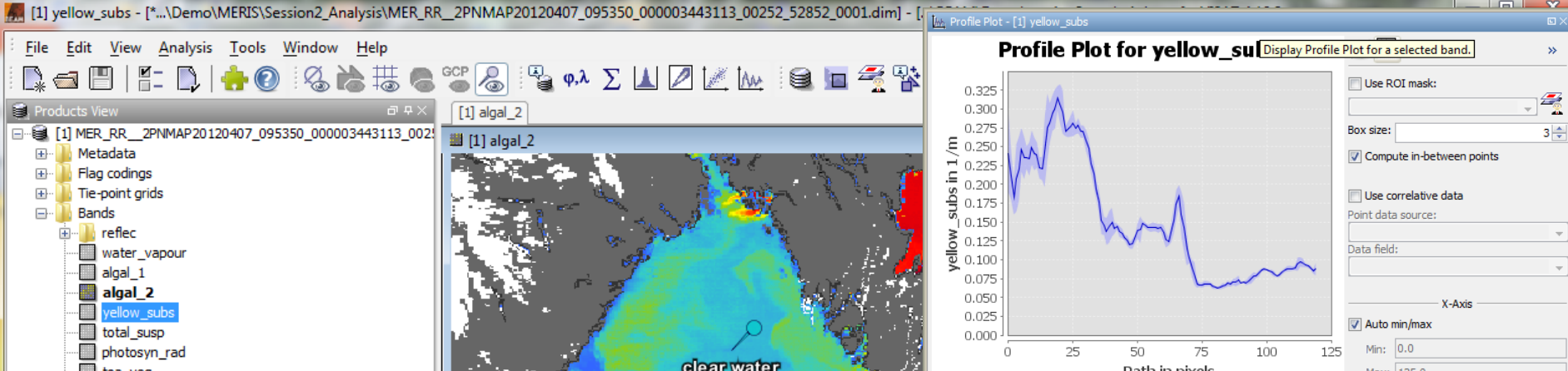
Log₁₀

More Options

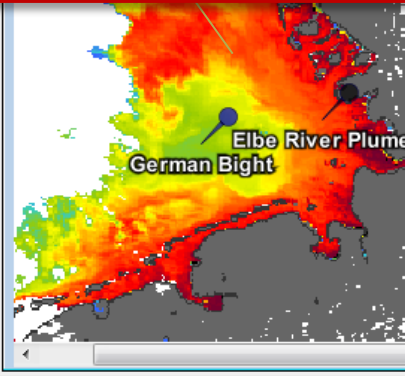
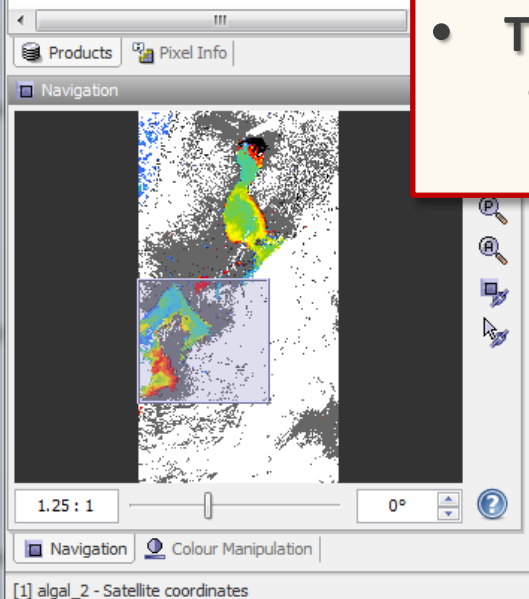
Navigation Colour Manipulation





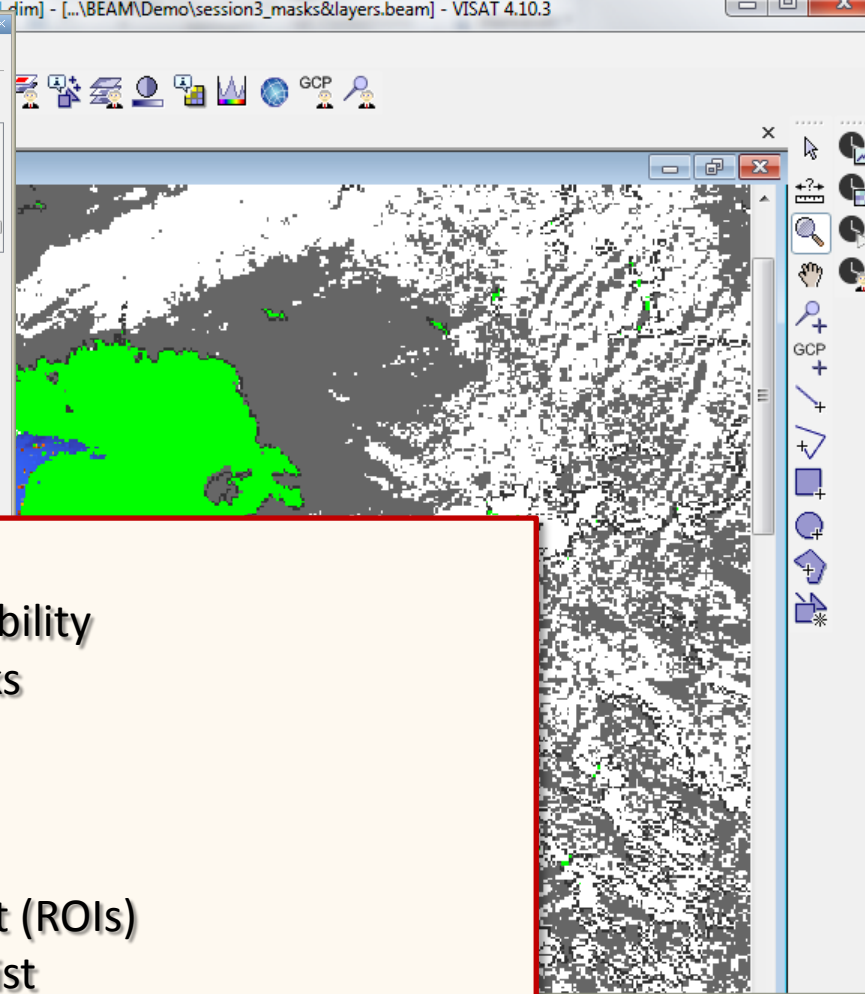
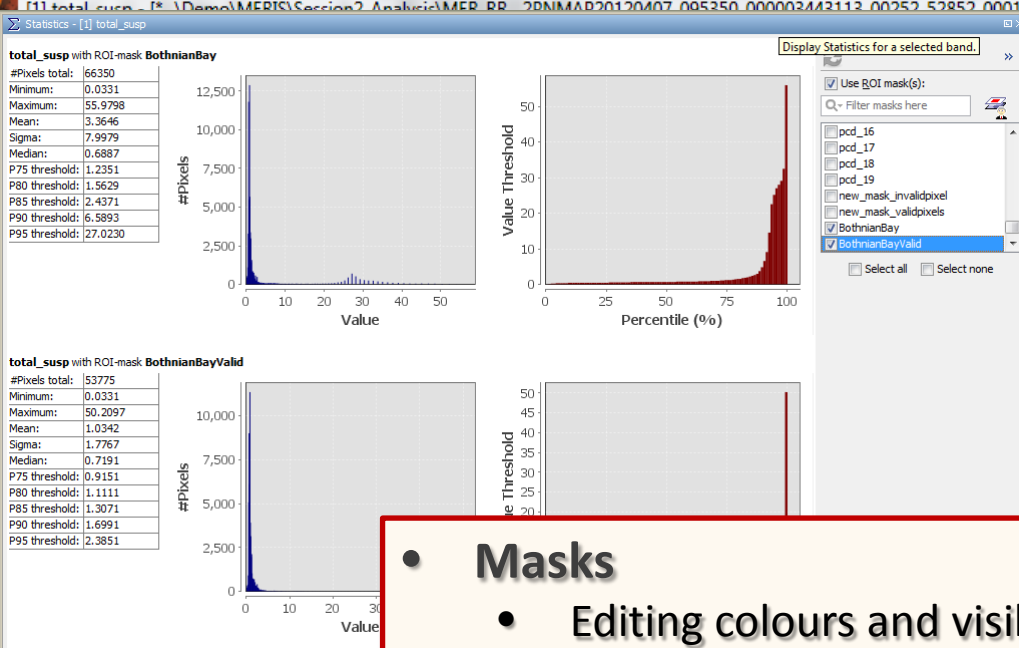


- **Pins**
 - Tabular view on band information of dedicated positions
- **Spectrum View**
 - Mouse over
 - Linked to pins (colours and selection)
- **Transect**
 - Pixel values along linear geometry and surroundings



Pin Manager - [1] MER_RR_2PNMAP20120407_095350_000003443113_00252_52852_0001

X	Y	Lon	Lat	Label	algal_2	yellow_subs	total_sus
223.54016	1014.4187	10.251525	58.12331	clear water	0.67107594	0.0267723	0.40
79.47578	1129.4962	7.3274684	57.214355	Bloom1	3.0774355	0.0489432	0.69
130.4803	1280.4299	7.620242	55.563538	Bloom2	14.1125765	0.3855058	8.4
143.50153	1411.4415	7.3553734	54.18548	German Bight	2.302527	0.055571437	1.24
208.49533	1398.37	8.417167	54.196457	Elbe River Plu...	13.610004	1.660974	32.4



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

cloud_albedo
cloud_opt_thick
cloud_top_press
cloud_type
l2_flags

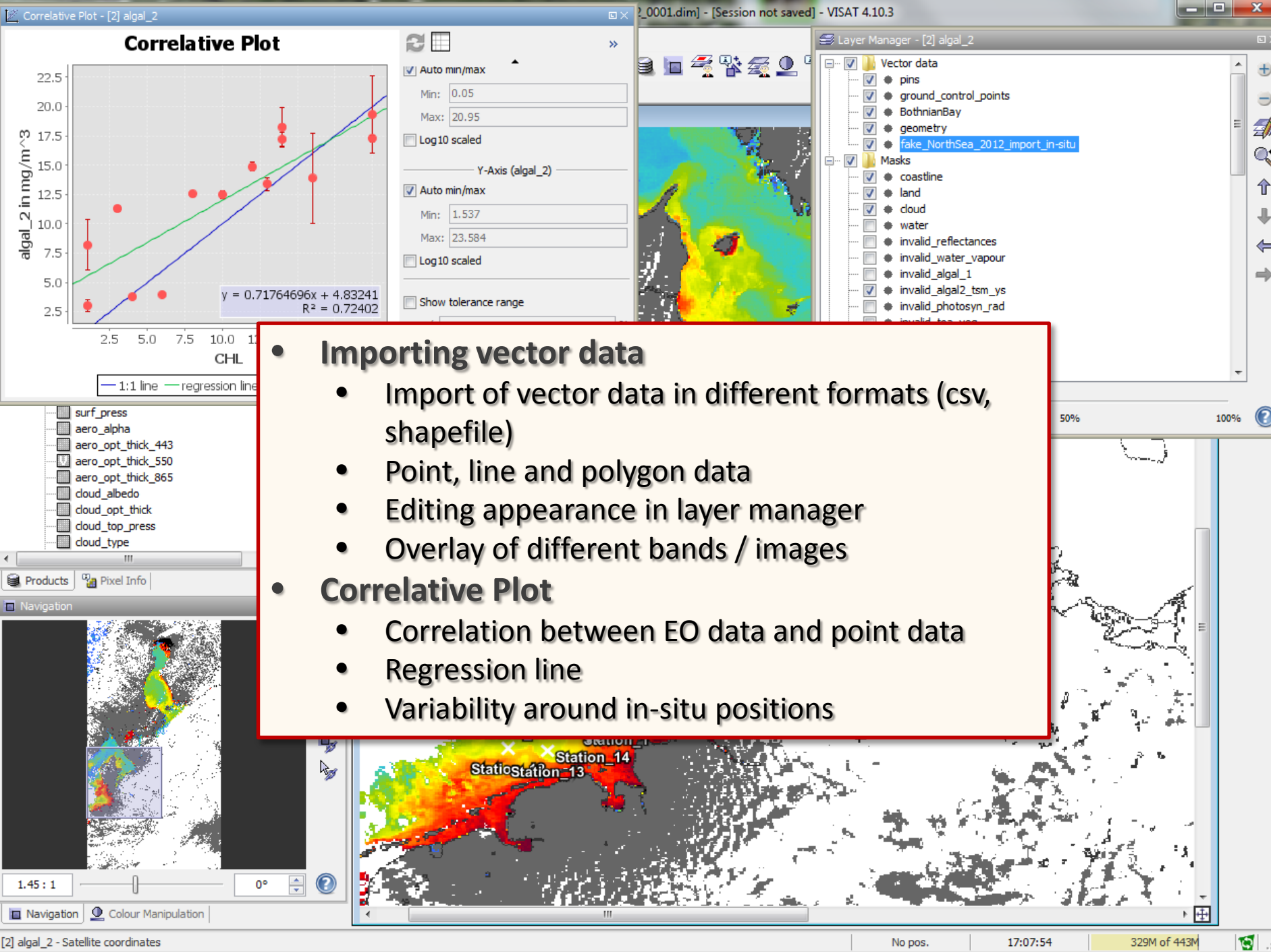
Products Pixel Info

Navigation

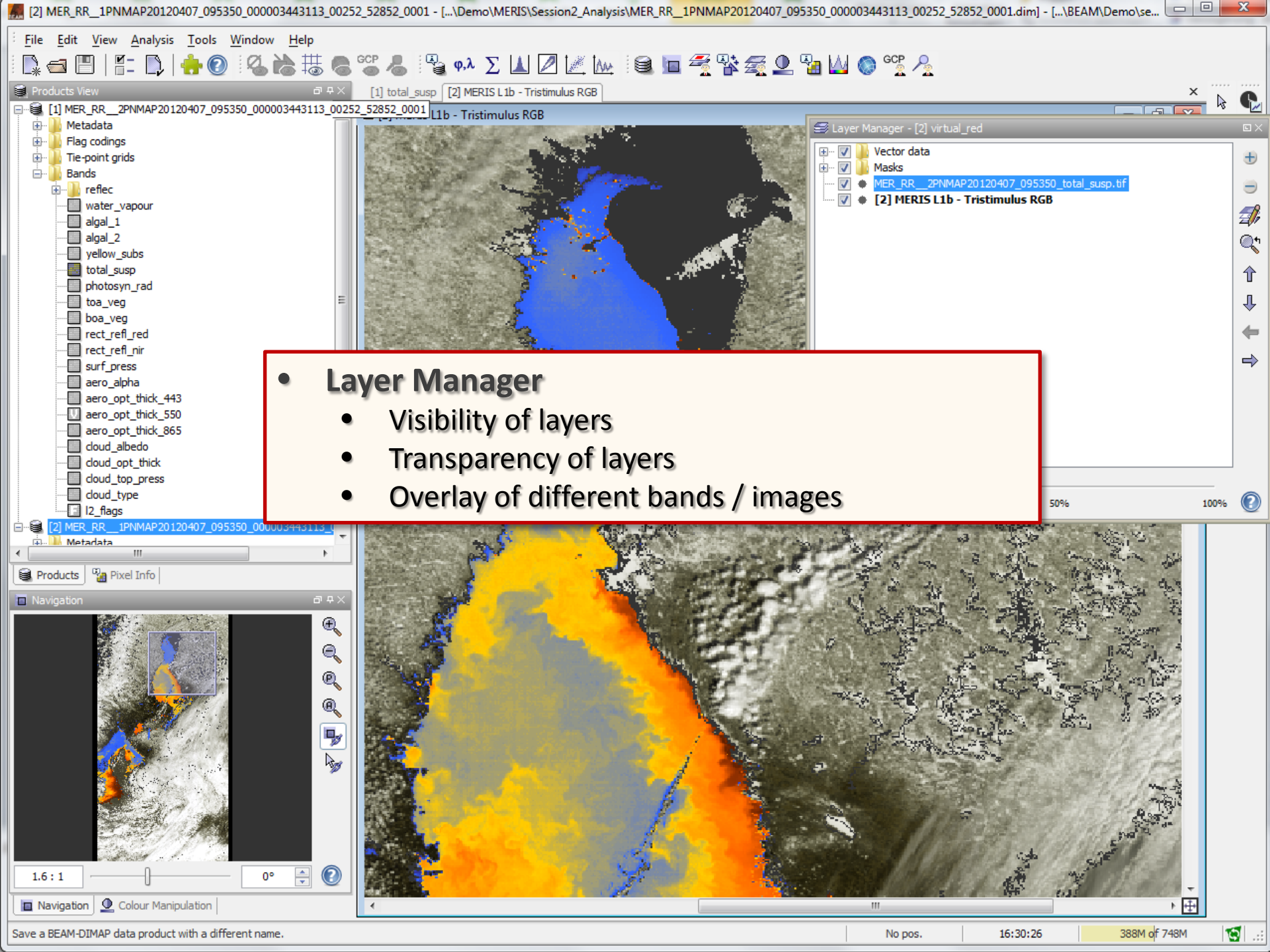
1.6 : 1 0°

Navigation Colour Manipulation

Name	Type	Colour	Tra...	Description
white_scatterer	Maths	204...	0.5	Presence of white scatterer in water
cosmetic	Maths	204...	0.5	Cosmetic pixel (from level-1b)
suspect	Maths	204...	0.5	Suspect pixel (from level-1b)
pcd_1_13	Maths	255...	0	Uncertain normalized surface reflectance
pcd_14	Maths	255...	0	Uncertain total water vapour content
pcd_15	Maths	255...	0	Uncertain algal pigment index 1 or cloud top pressure
pcd_16	Maths	255...	0	Uncertain yellow substance and total suspended matte
pcd_17	Maths	255...	0	Uncertain algal pigment index 2 or bottom of atmosphe
pcd_18	Maths	255...	0	Uncertain PAR or cloud albedo or land surface pressur
pcd_19	Maths	255...	0	Uncertain aerosol type and optical thickness or cloud o
new_mask_45	Maths	0, 2...	0	l2_flags.WATER and (l2_flags.PCD_17 or l2_flags.ICE



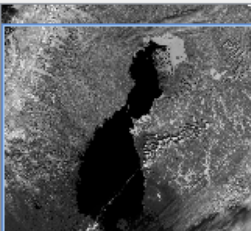
- **Importing vector data**
 - Import of vector data in different formats (csv, shapefile)
 - Point, line and polygon data
 - Editing appearance in layer manager
 - Overlay of different bands / images
- **Correlative Plot**
 - Correlation between EO data and point data
 - Regression line
 - Variability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

Pixel Extraction

Input/Output | Parameters

Coordinates:

Name	Latitude	Longitude	Date/Time
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

Note: The expression might not be applicable to the selected products

Use expression as filter Export expression

Sub-scenes: Enable export Border size:

KMZ coordinates: Export found coordinates in Google KMZ format

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:

Output path reflectance

Output transmittance

Output normalised bidirectional reflectances

Output cloud top pressure

Land detection expression:

Cloud/Ice detection expression:

Water algorithm:

Tsm conversion exponent:

Tsm conversion factor:

Chl conversion exponent:

Chl conversion factor:

Spectrum out of scope threshold:

Invalid pixel expression:

Alternative inverse water neural net (optional):

Alternative forward water neural net (optional):

Tools Window Help

Create Band by Band Maths...

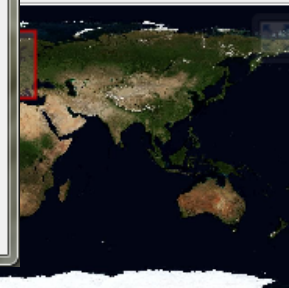
Create DEM-related Bands...

Create NIRS Bands (ASAP)

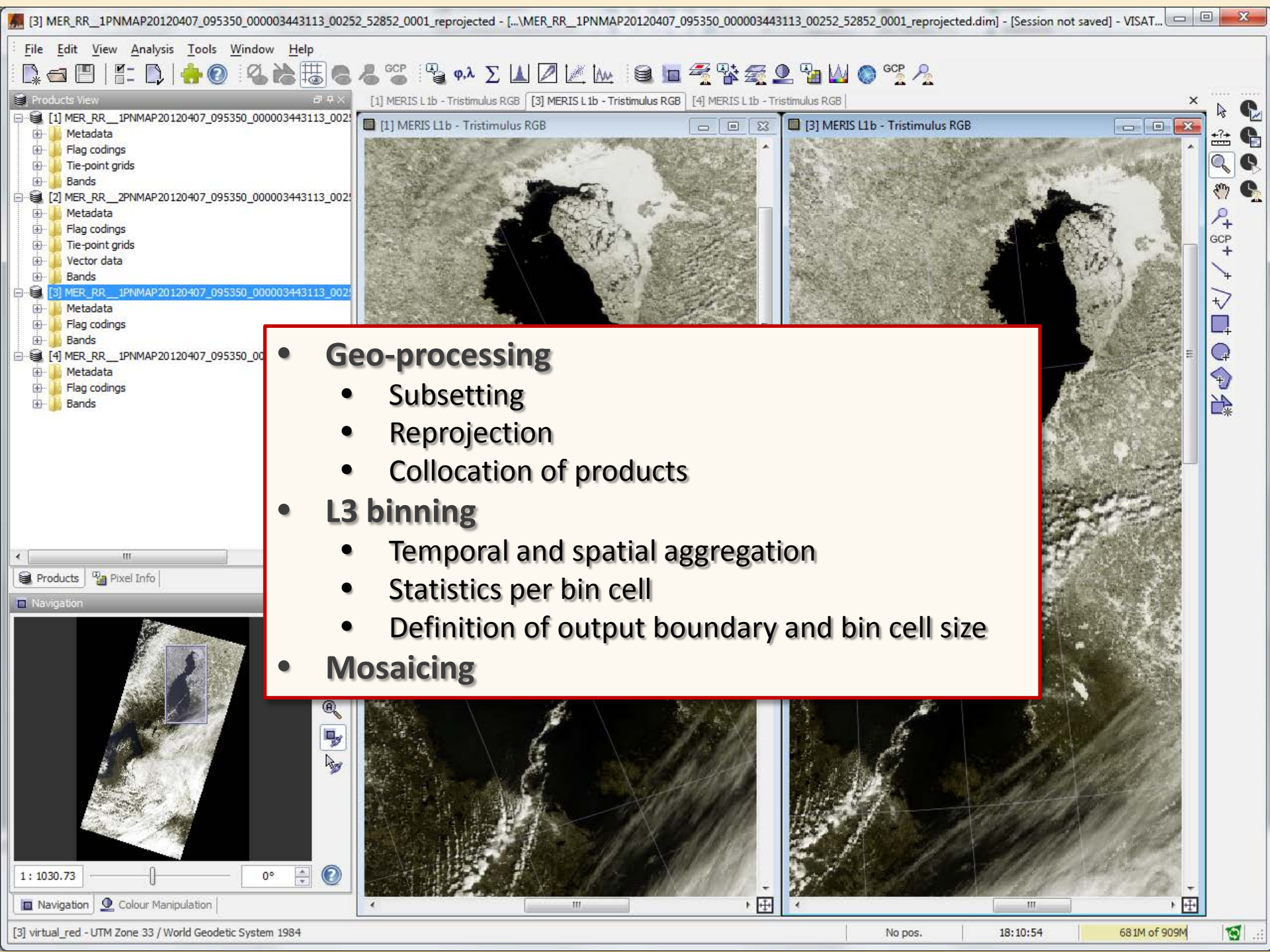
2_52852_0001

30.0 Pixel size X:

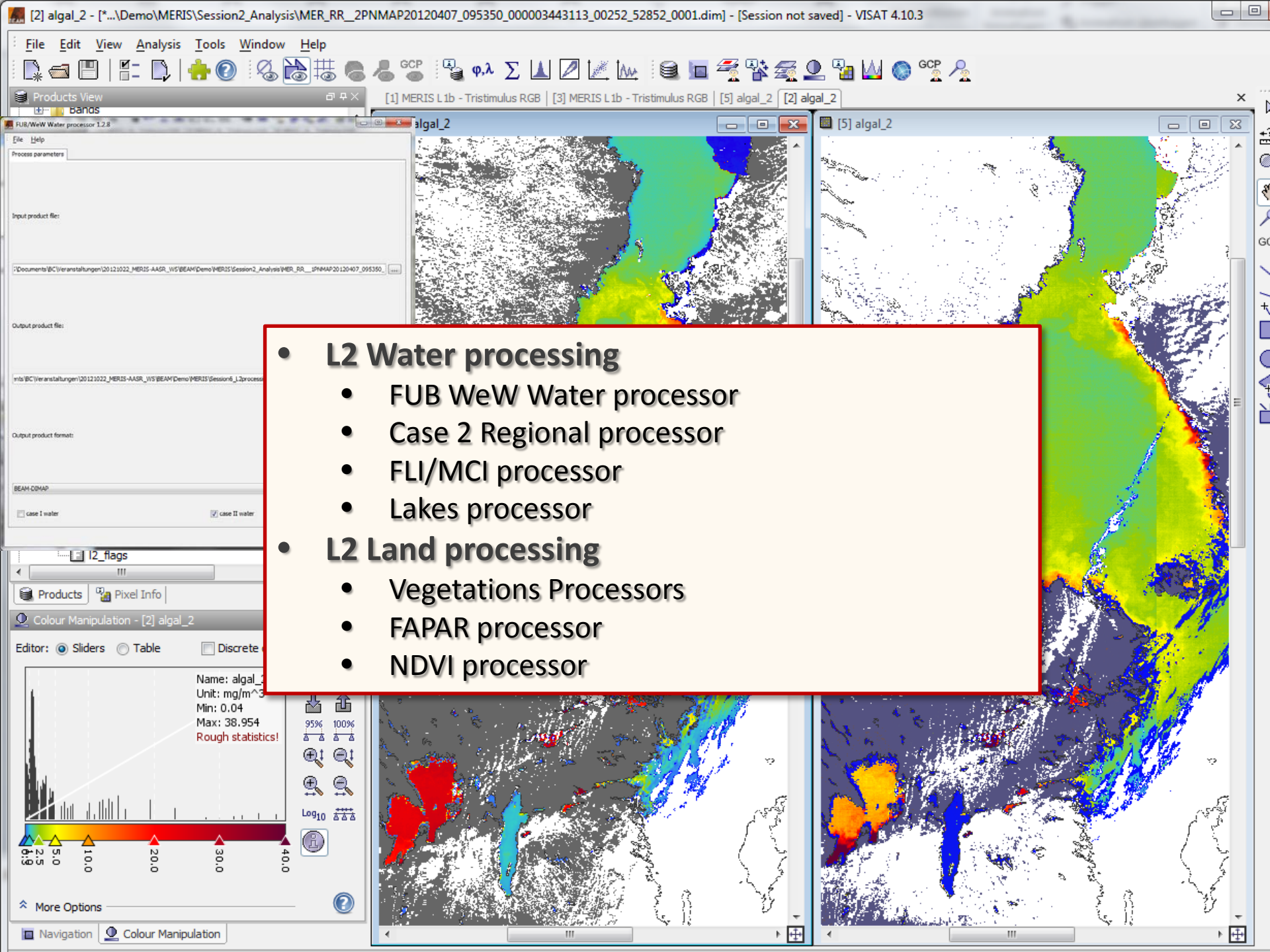
35.0 Pixel size Y:



Display source products



- **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

The screenshot displays the VISAT 4.10.4-SNAPSHOT software interface, which is used for processing Sentinel-3 data. The main window is titled "[1] SDR_4_CAM1 - [*...]manifest.safe - [Session not saved] - VISAT 4.10.4-SNAPSHOT".

The interface is divided into several panels:

- Products View (Left):** A tree view showing the data structure. The selected product is "SDR_4_CAM1" under the "SDR_4" folder. Other products include "longitude_CAM1" through "longitude_CAM5", "SDR_1" through "SDR_3", and "SDR_1_er" through "SDR_3_er".
- Main View (Center):** Two panels showing the data. The left panel, titled "[1] SDR_4_CAM1", displays a grayscale image of the Earth's surface, likely a coastal area, with a prominent white and gray pattern. The right panel, titled "[2] B2", displays a color image of the same area, showing green vegetation and brown land. A circular logo is visible in the top-left corner of the right panel.
- Colour Manipulation (Bottom Left):** A panel for adjusting the color of the data. It includes a histogram, a color bar, and various controls. The "Name" is "SDR_4_CAM1", "Unit" is "null", "Min" is "0.0", and "Max" is "0.044". The "Rough statistics!" section is visible. The "Editor" is set to "Sliders".
- Bottom Status Bar:** Shows the current product name "[1] SDR_4_CAM1 - Satellite coordinates", the coordinates "[1] 457,2697 (L1)", the time "19:04:53", and the memory usage "554M of 910M".

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

[3] chlorophyll_concentration_in_sea_water_mean_20100403.020000.000 - [Product not saved] - [Session not saved] - VISAT 4.10-SNAPSHOT

File Edit View Analysis Tools Window Help

Products View

Time Series Manager - [3] weekly_MC_2010

Time Series Player

Date: 03-Apr-2010 02:00:00

Time Series Player

01-Jan-2010 01:00:00 22-Nov-2010 01:00:00

Speed: [Slider]

Time Series Matrix

Date: 03-Apr-2010 02:00:00

1.0307	1.0307	1.5314	1.9922	1.9922
1.1668	1.4764	2.3660	2.3660	3.0557
1.6981	2.3255	2.3255	3.0570	3.0570
2.1964	2.1964	3.1740	3.1740	4.4884
2.2920	3.2374	3.2374	4.0418	4.0418

Time Series Matrix

Time Series Graph

Chlorophyll Concentration (mg/m³)

Time

chlorophyll_concentration_in_sea_water_mean_HELGO CHL_HELGO

Valid expression

r.chlorophyll_con... | chlorophyll_concentration_in_sea_water_mean > 0.01

Pin Manager - [3] weekly_MC_2010

X	Y	Lon	Lat	Label
1066.9026	865.891	6.4999995	53.6733	ES1
1153.4813	819.04425	7.4332995	54.1783	UFSD8
1215.3286	812.3928	8.1	54.25	HELGO
989.6005	804.6653	5.6667	54.3333	NEFB
1093.1833	804.6653	6.7833004	54.3333	NGW8
974.1364	773.7373	5.5	54.6667	SWWBA
1190.5879	773.7373	7.8333	54.6667	AMRU2
1093.1833	772.1972	6.7833004	54.6833	NSB3
974.1364	742.8182	5.5	55.0	NSGR2
1093.1833	742.8182	6.7833004	55.0	URST3

Colour Manipulation - [3] chlorophyll_concentration_in_sea_water_mean

Editor: Sliders Table

Name: chlorophyll_concentration_in_sea_water_mean_20100403.020000

Unit: null

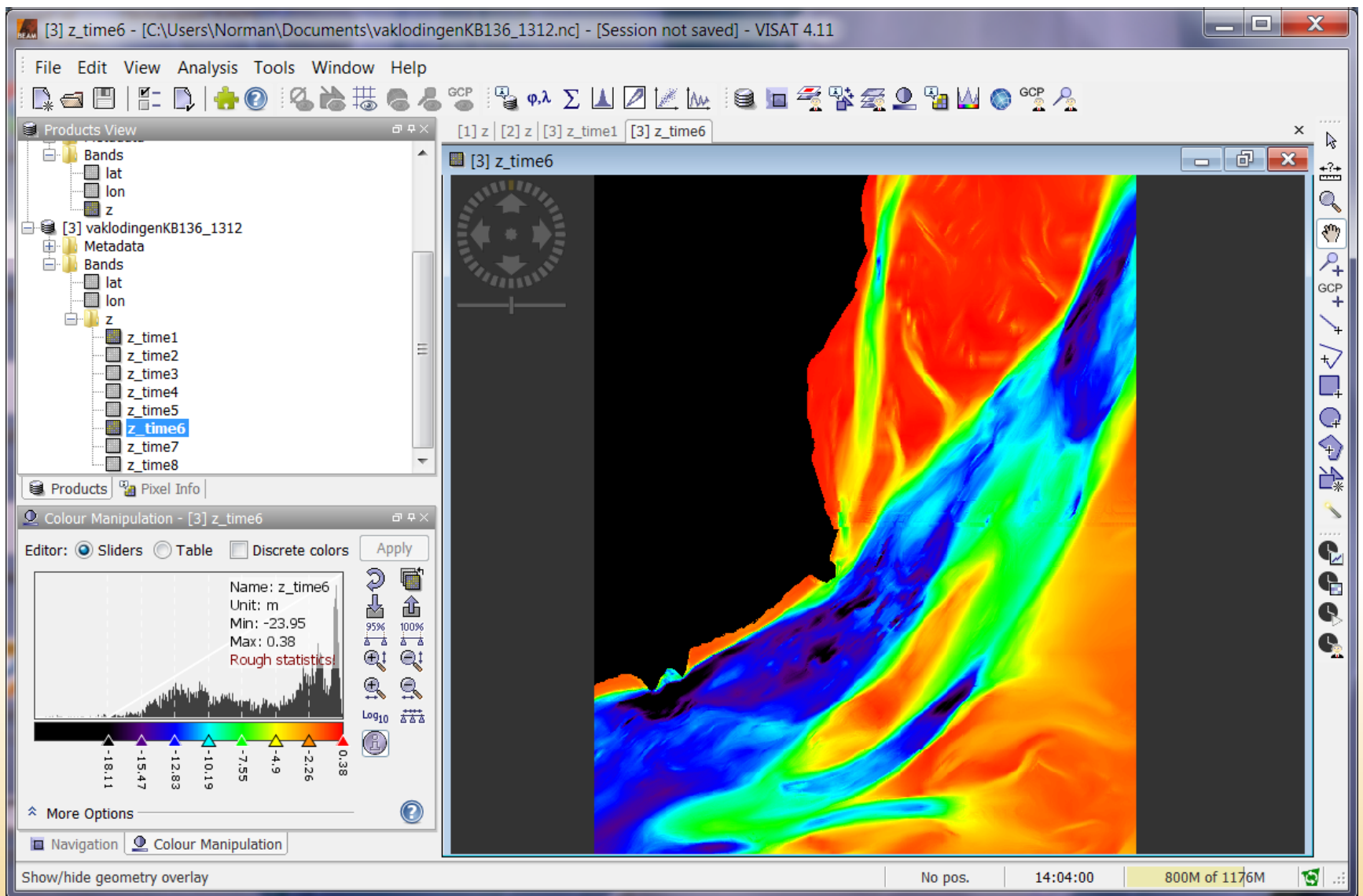
Min: 0.0

Max: 40.392

Rough statistics!

19 SCROLL LOCK: ON

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



l2gen

Main Products Subsetting Options Thresholds IOP Options Processing Options Ancillary Inputs Miscellaneous Calibration Options

IOP Options

giop_adg_file

giop_adg_opt

giop_adg_s

giop_aph_file ... filter:

giop_aph_opt

giop_aph_s

giop_bbp_file ... filter:

giop_bbp_opt

giop_bbp_s

giop_fit_opt

giop_grd

giop_maxiter

giop_rrs_opt

giop_wave

gsm_adg_s

gsm_aphs

gsm_aphw

gsm_bbp_s

gsm_fit

gsm_opt

iop_opt

qaa_adg_s

qaa_wave

Restore Defaults (IOP Options only)

Open in SeaDAS

Run Cancel Apply ?

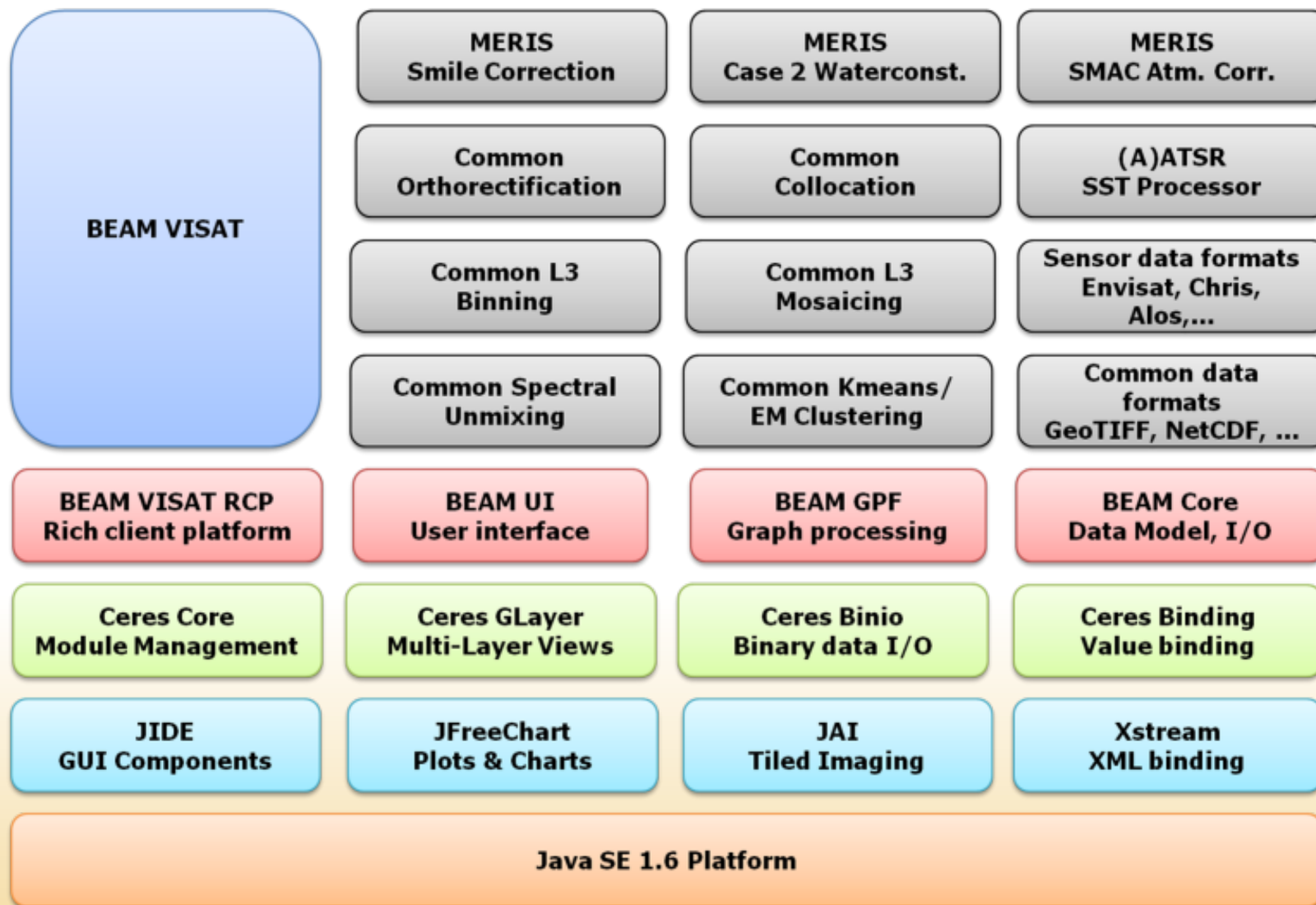
SeaDAS 7.0 Objectives (cont.)

- 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

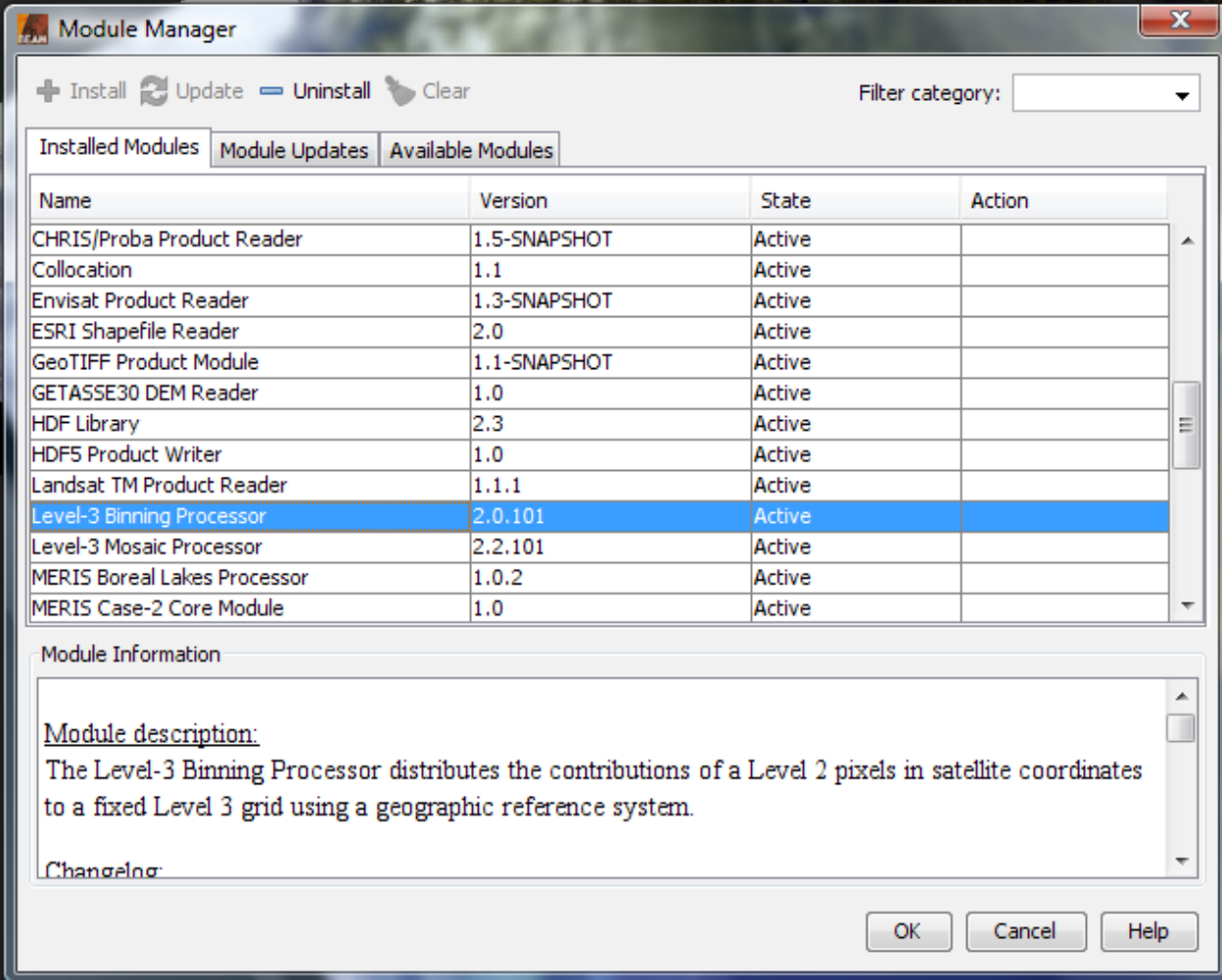
Thanks for your attention!

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

Architecture Overview



VISAT Module Manager



The screenshot shows the VISAT Module Manager window. At the top, there are buttons for '+ Install', 'Update', 'Uninstall', and 'Clear'. A 'Filter category:' dropdown menu is on the right. Below these are three tabs: 'Installed Modules', 'Module Updates', and 'Available Modules'. The 'Installed Modules' tab is active, displaying a table with the following data:

Name	Version	State	Action
CHRIS/Proba Product Reader	1.5-SNAPSHOT	Active	
Collocation	1.1	Active	
Envisat Product Reader	1.3-SNAPSHOT	Active	
ESRI Shapefile Reader	2.0	Active	
GeoTIFF Product Module	1.1-SNAPSHOT	Active	
GETASSE30 DEM Reader	1.0	Active	
HDF Library	2.3	Active	
HDF5 Product Writer	1.0	Active	
Landsat TM Product Reader	1.1.1	Active	
Level-3 Binning Processor	2.0.101	Active	
Level-3 Mosaic Processor	2.2.101	Active	
MERIS Boreal Lakes Processor	1.0.2	Active	
MERIS Case-2 Core Module	1.0	Active	

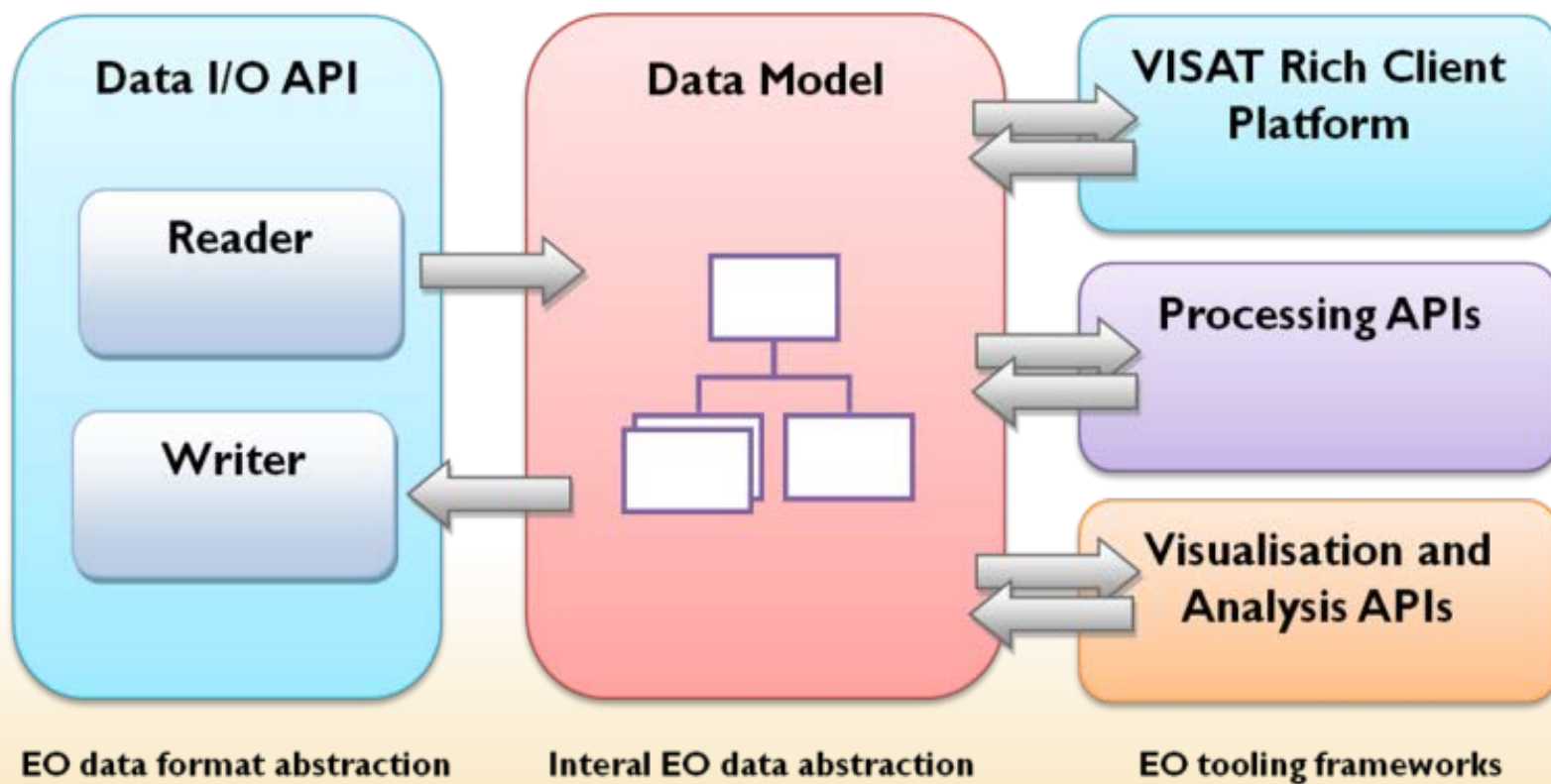
Below the table is a 'Module Information' section with a text area containing the following text:

Module description:
The Level-3 Binning Processor distributes the contributions of a Level 2 pixels in satellite coordinates to a fixed Level 3 grid using a geographic reference system.

Changelog:

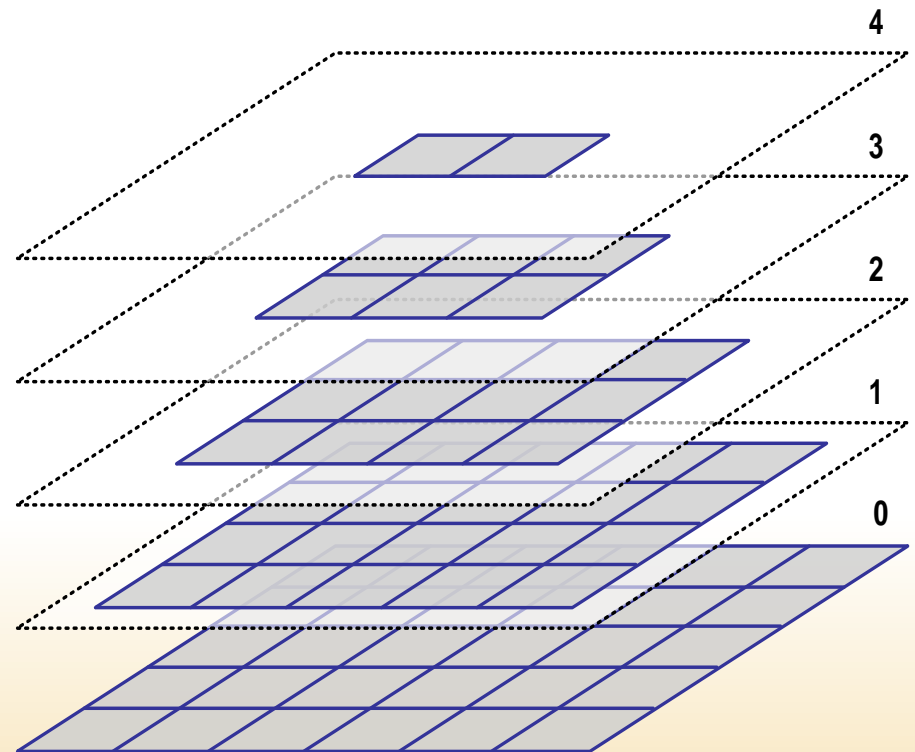
At the bottom right of the window are 'OK', 'Cancel', and 'Help' buttons.

Generic EO Data Model

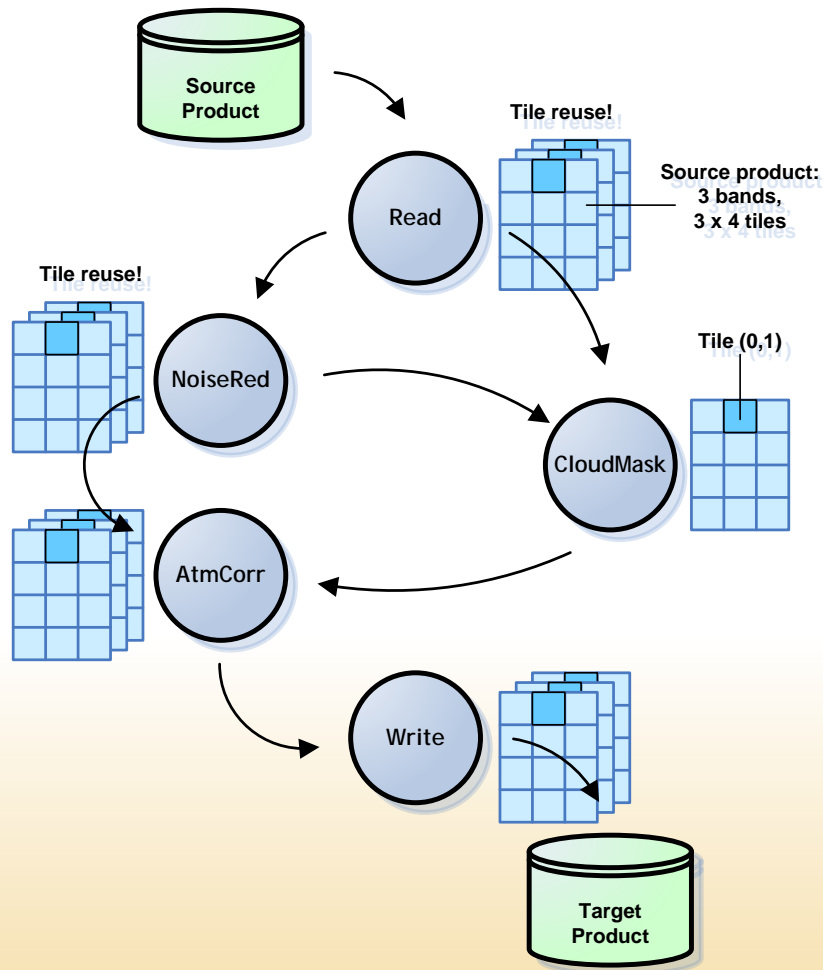


Raster Data Management

- 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)
```