Hungarian Space Office

SZENT ISTVÁN UNIVERSITY

esa

→ 7th ADVANCED TRAINING COURSE ON LAND REMOTE SENSING

4–9 September 2017 | Szent István University | Gödöllő, Hungary

LST RETRIEVAL USING THE SYNERGY OF S3-OLCI AND SLSTR

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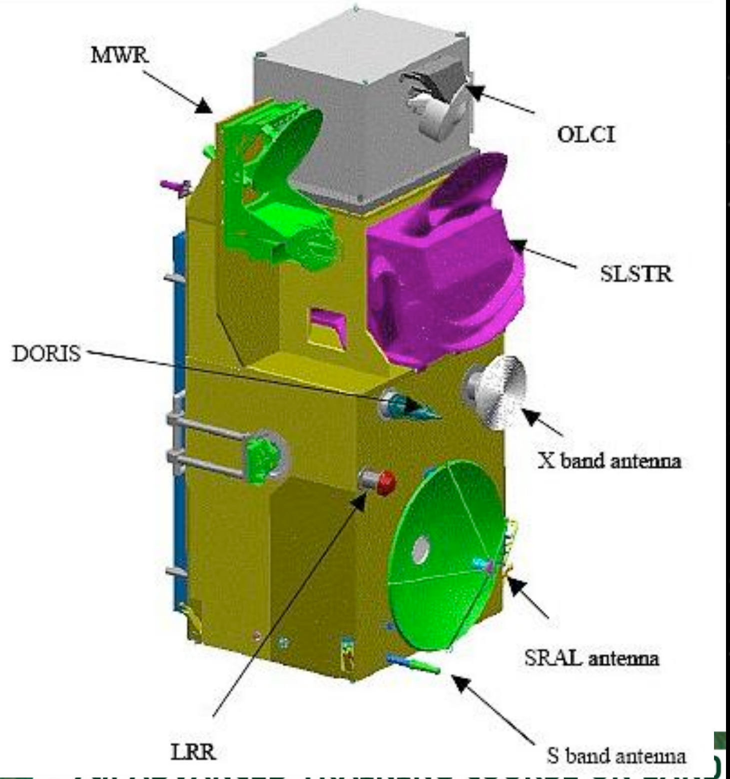
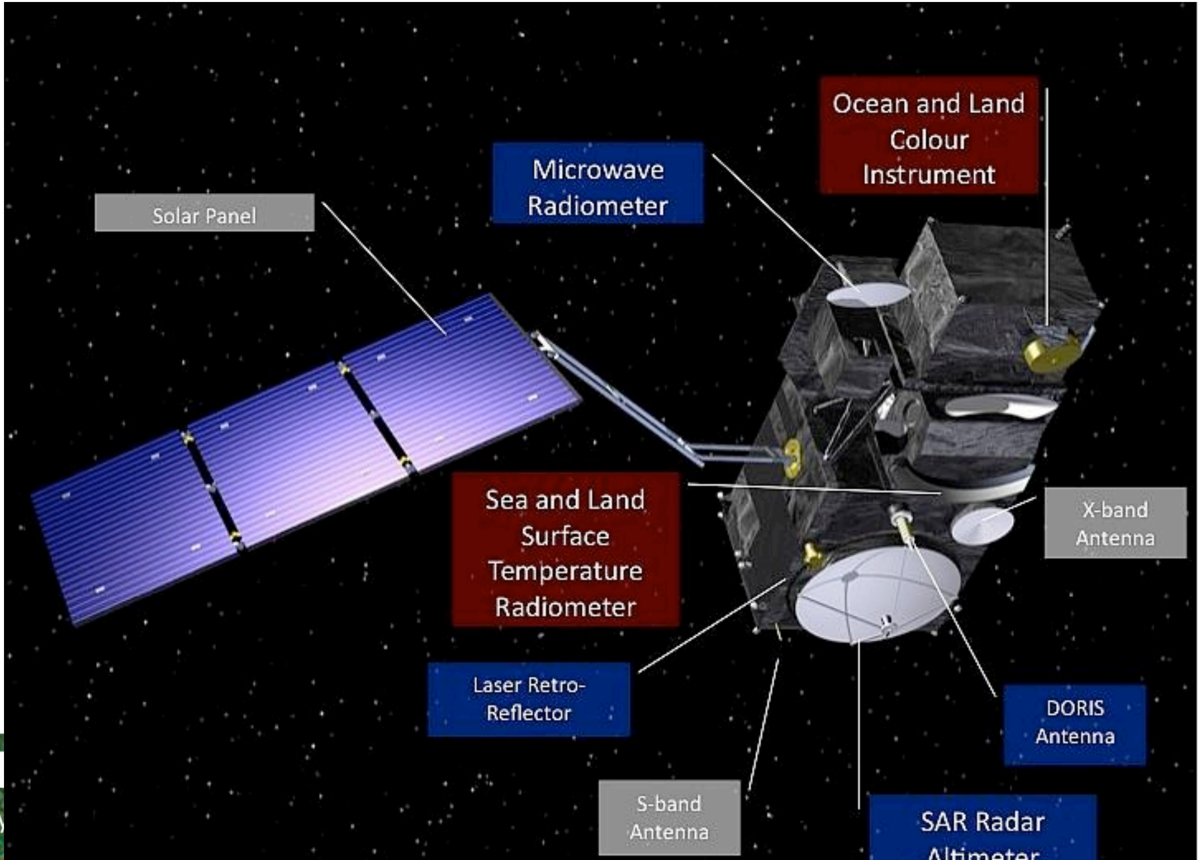
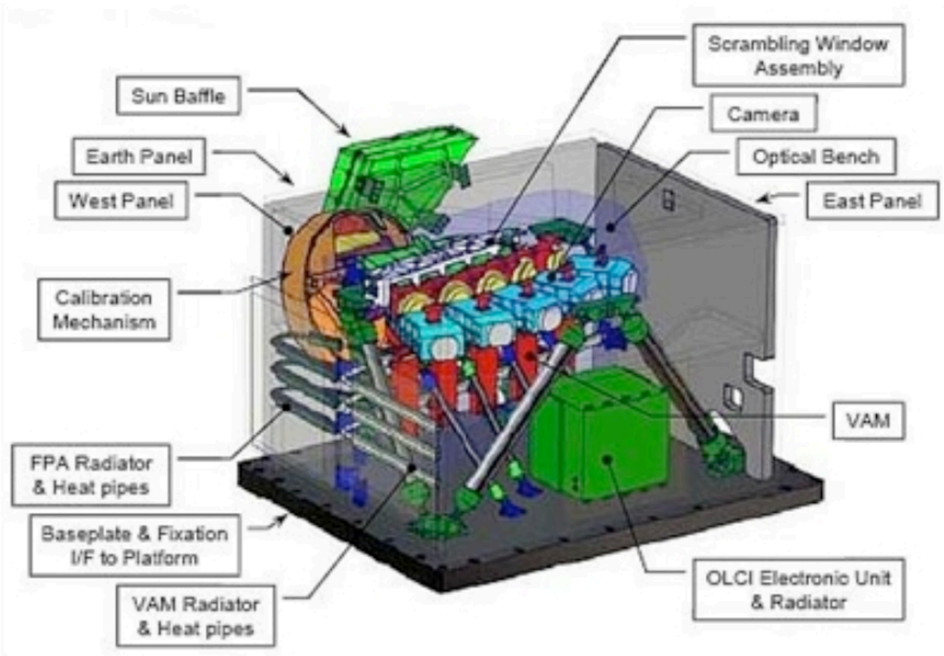
Brockmann Consult (Germany) + Image Processing Laboratory (UV, Spain)

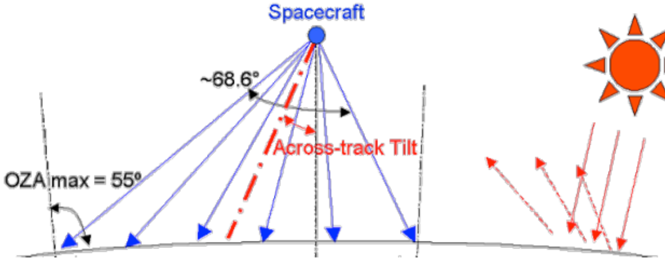
SENTINEL-3 SATELLITE OLCI & SLSTR SENSORS

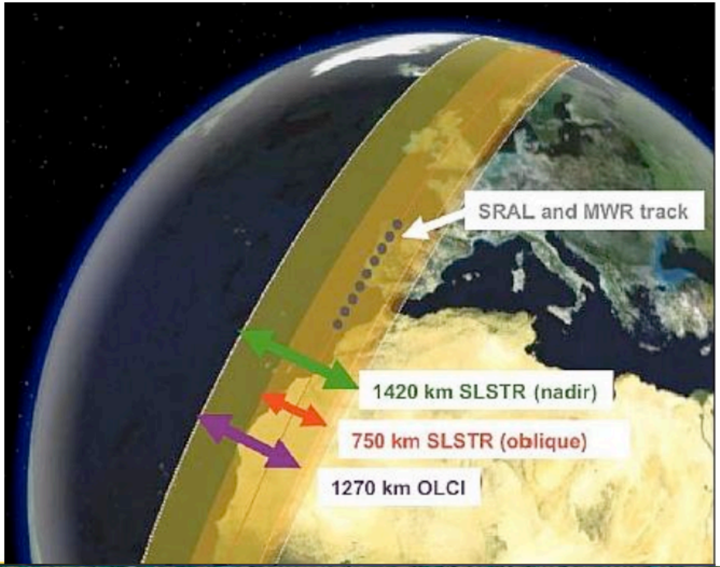




Ocean and Land Colour Instrument: OLCI







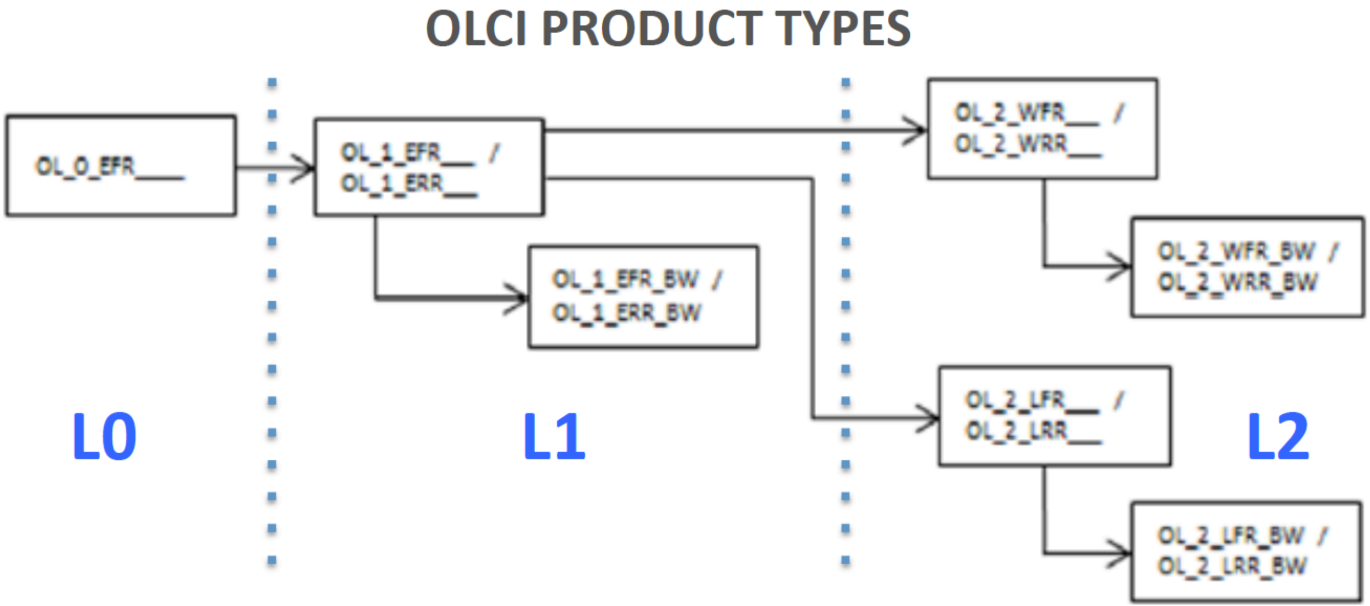
Images credit: ESA

Ocean and Land Colour Instrument: OLCI

Swath	1 440 km
SSI at SSP (km)	300 m
Calibration	MERIS type calibration arrangement with spectral calibration using a doped Erbium diffuser plate, PTFE diffuser plate and dark current plate viewed approximately every 2 weeks at the South Pole ecliptic. Spare diffuser plate viewed periodically for calibration degradation monitoring
Detectors	ENVISAT MERIS heritage back-illuminated CCD55-20 frame-transfer imaging device (780 columns by 576 row array of 22.5 µm square active elements).
Optical scanning design	Push-broom sensor. Five cameras recurrent from MERIS dedicated Scrambling Window Assembly (SWA) supporting five Video Acquisition Modules (VAM) for analogue to digital conversion
Spectral resolution	1.25 nm (MERIS heritage), 21 bands.
Radiometric accuracy	< 2% with reference to the sun for the 400-900 nm waveband and < 5% with reference to the sun for wavebands > 900 nm. 0.1% stability for radiometric accuracy over each orbit and 0.5% relative accuracy for the calibration diffuser BRDF.
Radiometric resolution	< 0.03 W m^{-2} sr^{-1} mm^{-1} (MERIS baseline)
Mass	150 kg
Size	1.3 m^3
Design lifetime	7.5 years

MERIS Bands	λ center	Width
Yellow substanace/detrital pigments	412.5	10
Chl.. Abs. Max	442.5	10
Chl & other pigments	490	10
Susp. Sediments, red tide	510	10
Chl. Abs. Min	560	10
Suspended sediment	620	10
Chl. Abs, Chl. fluorescence	665	10
Chl. fluorescence peak	681.25	7.5
Chl. fluorescence ref., Atm. Corr.	708.75	10
Vegetation, clouds	753.75	7.5
O_2 R-branch abs.	761.25	2.5
O_2 P-branch abs.	778.75	15
Atm corr	865	20
Vegetation, H_2O vap. Ref.	885	10
H_2O vap., Land	900	10
New OLCI bands	**λ center**	**Width**
Aerosol, in-water property	400	15
Fluorescence retrieval	673.75	7.5
Atmospheric parameter	764.375	3.75
Cloud top pressure	767.5	2.5
Atmos./aerosol correction	940	20
Atmos./aerosol correction	1020	40

OLCI product types



LEVEL 0

EFR	*Earth observation Full Resolution*

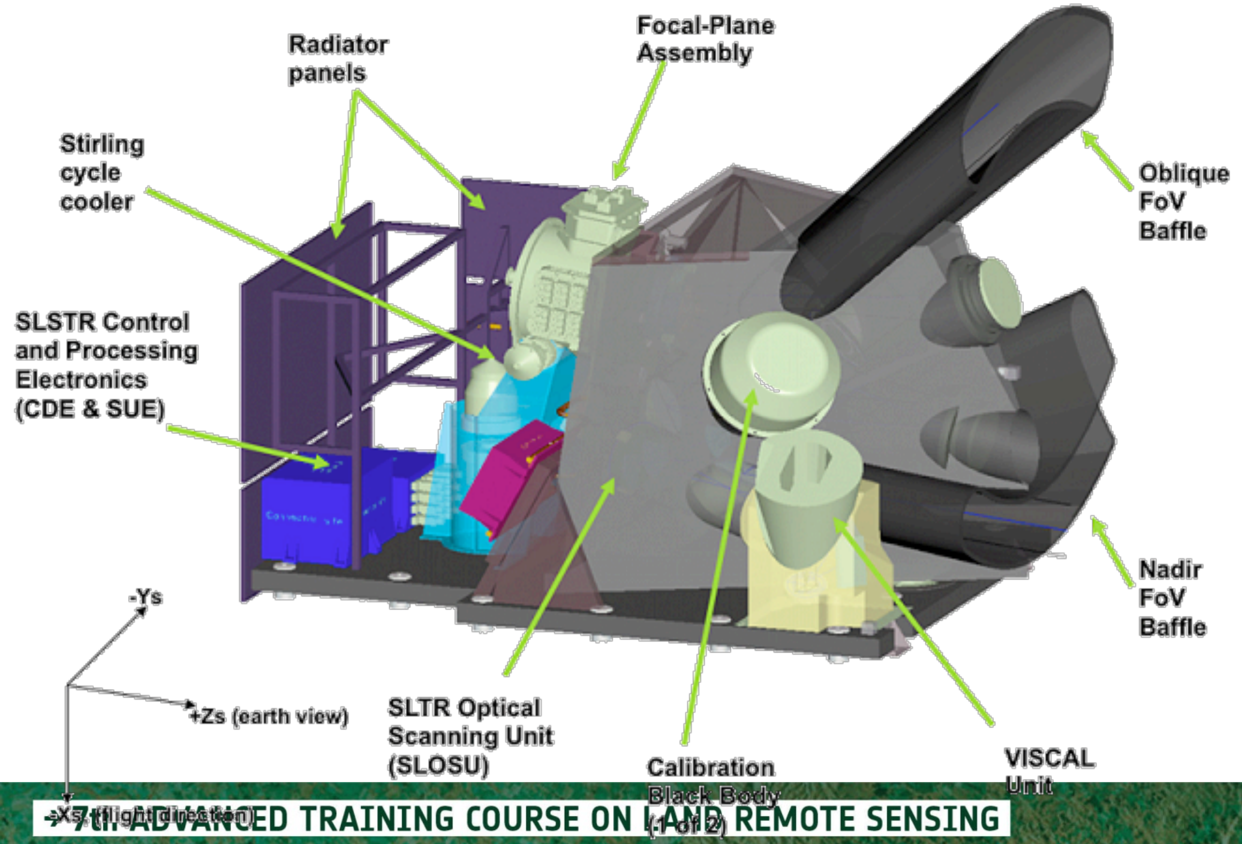
LEVEL 1

EFR	*Earth observation Full Resolution (calibrated)*
ERR	*Earth observation Reduced Resolution (cal.)*
EFR_BW	*EFR browse product*

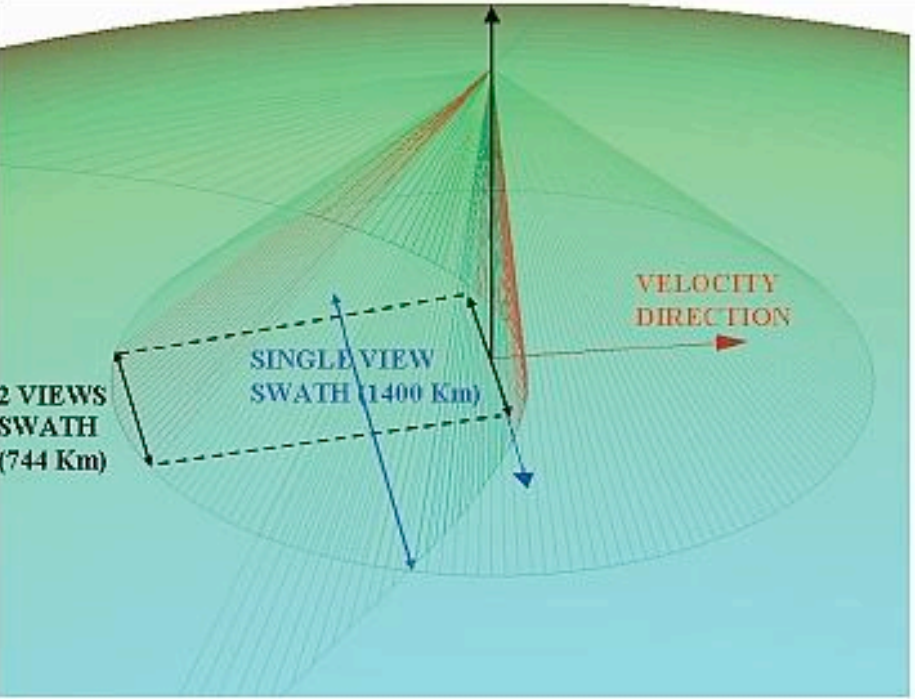
LEVEL 2

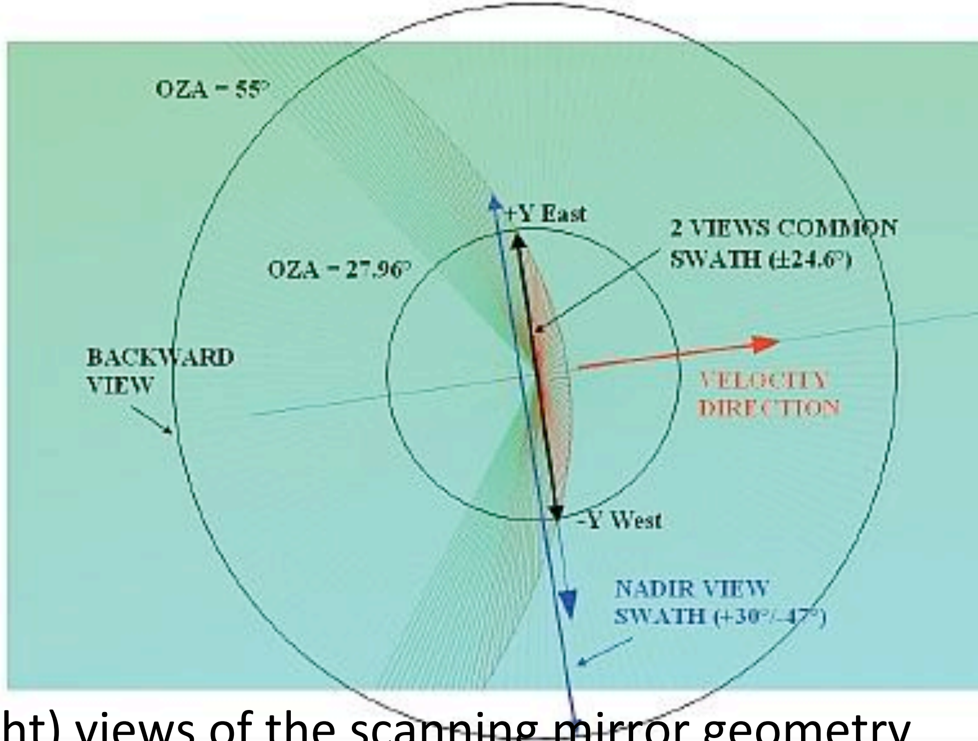
WFR	*Water and atmosphere Full Resolution*
WFR_BW	*WFR Browse Product*
WRR	*Water and atmosphere Reduced Res.*
LFR	*Land Full Resolution*
LRR	*Land Reduced Resolution*
Etc.	

Sea and Land surface temperature radiometer (SLSTR)



Sea and Land surface temperature radiometer (SLSTR)





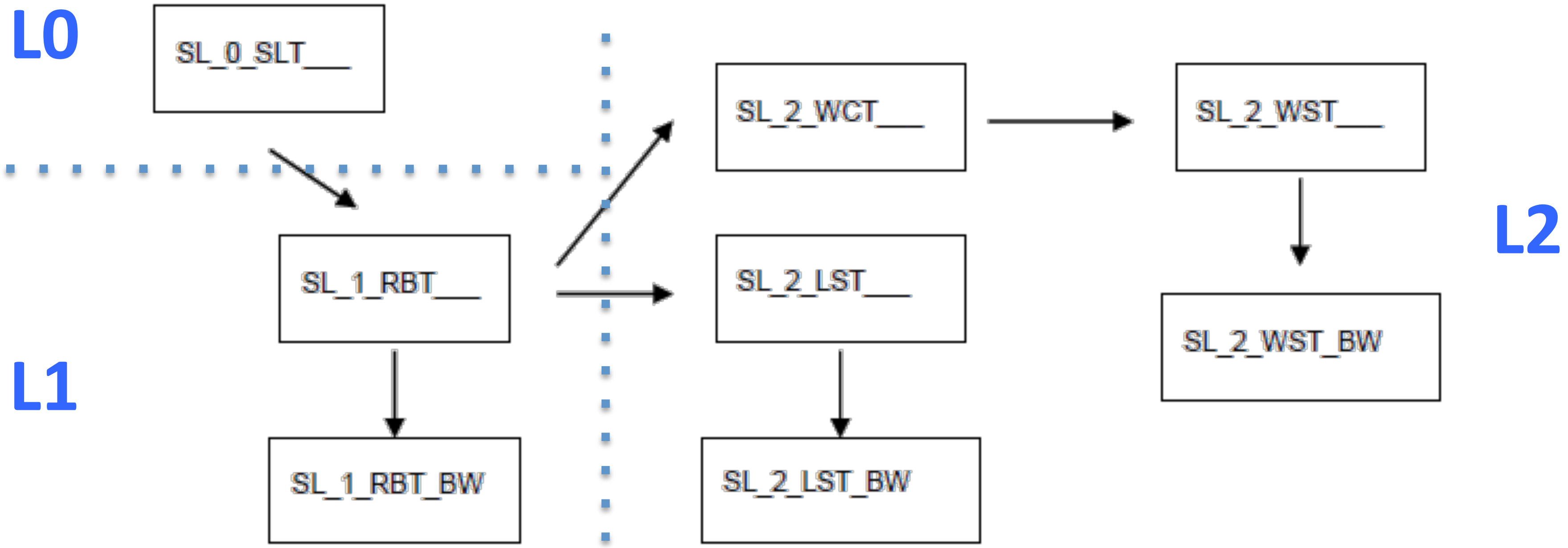
Backward inclined (left) and near nadir (right) views of the scanning mirror geometry

Image credit: SLSTR consortium

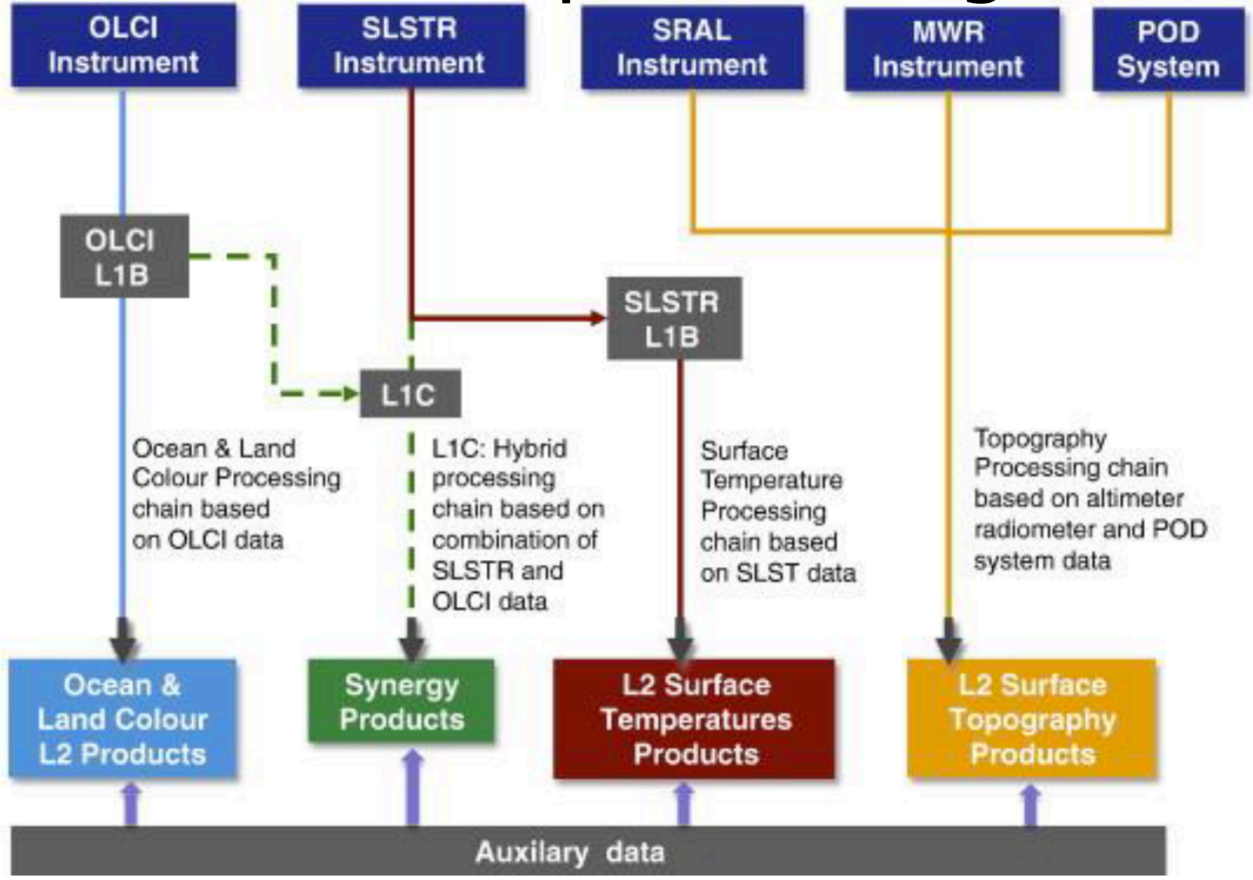
DATA AND PHYSICAL UNITS of SLSTR

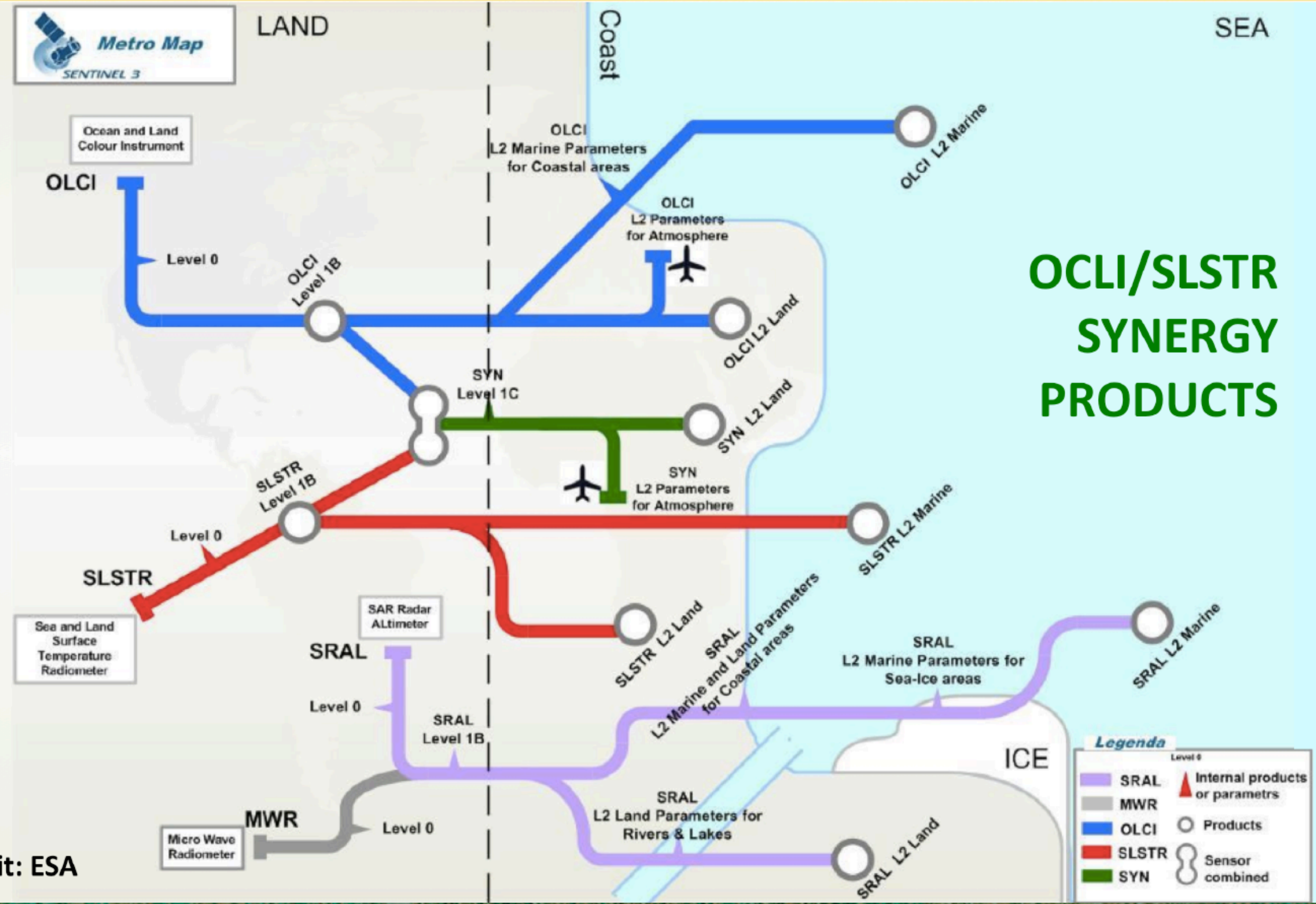
Performance	Parameters	SLSTR	AATSR & ATSR-1/2
Swaths	Nadir view	1 400 km	500 km
	Dual view	740 km	500 km
Global coverage revisit time	1 S/C (dual view)	1.9 days	7-14 days
		0.9 days	-
		1 day	7-14 days
		0.5 days	-
SSI at SSP (km)		0.5 km VIS-SWIR 1 km IR-fire	1 km
Spectral channels centre λ (μm)	VIS (not ATSR-1): SWIR: MWIR/TIR: Fire-1/2:	0.555; 0.659; 0.865; 1.375; 1.610; 2.25; 3.74; 10.85; 12; 3.74; 10.85	0.555; 0.659; 0.865; 1.610; 3.74; 10.85; 12; -
Radiometric resolution	VIS (a=0.5%): SWIR (a=0.5%):	SNR > 20 SNR > 20	SNR > 20 SNR > 20
	MWIR (T=270K): TIR (T=270K): Fire-1 (<500 K): Fire-2 (<400 K):	NeΔT < 80 mK NeΔT < 50 mK NeΔT < 1K NeΔT < 0.5 K	NeΔT < 80 mK NeΔT < 50 mK
Radiometric accuracy	VIS-SWIR: (a=2-100%)	< 2% (BOL) < 5% (EOL)	< 5%
	MWIR-TIR (265-310K): Fire (<500k):	< 0.1 k (goal) < 3 K	< 0.1 K
Life time (in orbit)		7.5 years	AATSR: 5 year design, operative since 2002; ATSR-2: 3 year design, operating from 1995 to 2008; ATSR-1: 3 year design, operating from 1991 to 2000

SLSTR PRODUCT TYPES



Sentinel-3 data processing chains





OCLI/SLSTR SYNERGY PRODUCTS

Image credit: ESA

OVERVIEW OF SENTINEL 3 TOOLBOX IN SNAP

ESA has developed a common architecture for all Sentinel Toolboxes call the **Sentinel Application Platform** (SNAP)

- The project is carried out by Brockmann Consult, Array Systems Computing and C-S called.

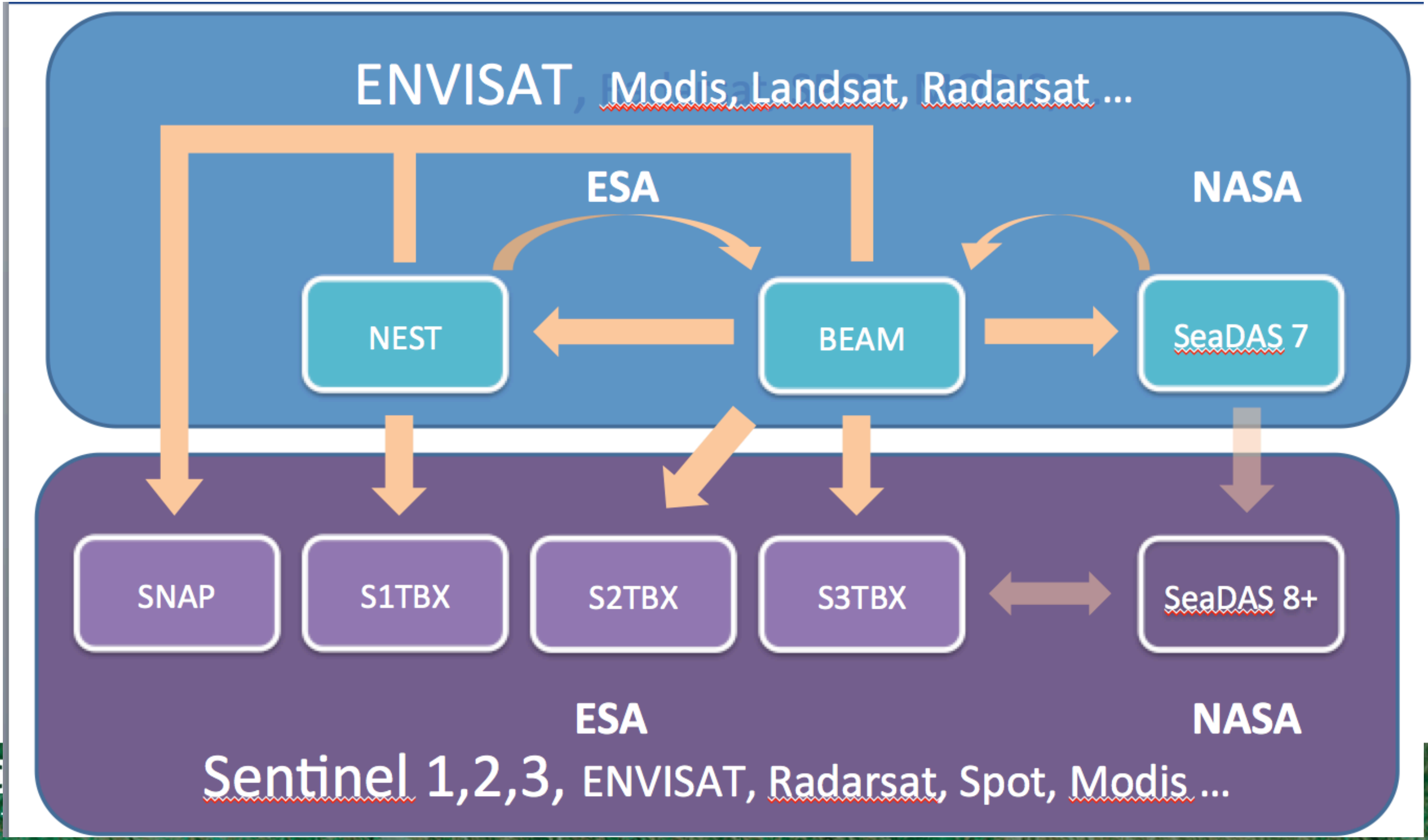
The SNAP architecture is ideal for Earth Observation processing and analysis due the following technological innovations: Extensibility, Portability, Modular Rich Client Platform, Generic EO Data Abstraction, Tiled Memory Management, and a Graph Processing Framework.

http://step.esa.int/main/toolboxes/snap/

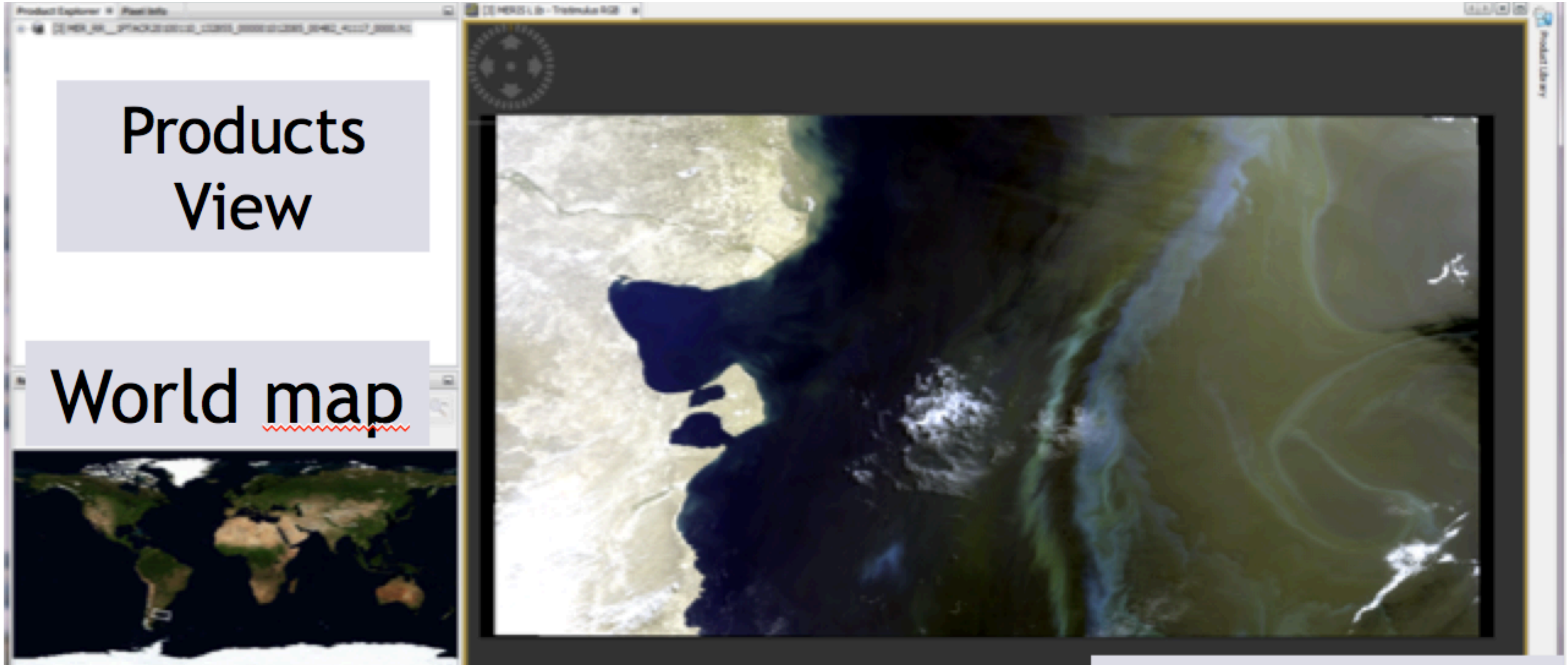
Sentinel Toolboxes Consortia

driven by user requirements, guided by user expertise, implemented by a experienced technical team

Heritage and Evolution



SNAP overview



Land surface temperature using a split-window algorithm

$$T_S = T_i + c_1 (T_i - T_j) + c_2 (T_i - T_j)^2 + c_0$$

$$+ (c_3 + c_4 W)(1 - \varepsilon) + (c_5 + c_6 W) \Delta\varepsilon \qquad (1)$$

where Ts is the LST (in K), $T_{i,j}$ are at-sensor brightness temperatures (in K), W is the atmospheric water vapor content (in g·cm^{-2} or cm), ε is the mean LSE 0.5·($\varepsilon_i + \varepsilon_j$), and Δε is the LSE difference ($\varepsilon_i - \varepsilon_j$). Subindices 'i' and 'j' refer to two different TIR bands, thus leading to the SW algorithm, or to one TIR band but two different view angles (e.g. nadir 'n' and oblique 'o' views), thus leading to the DA algorithm. Coefficients c_0 to c_6 are obtained from statistical regressions performed over simulated data.

J.A. Sobrino, J.C. Jiménez-Muñoz, G. Sòria, A.B. Ruescas, O. Danne, C. Brockmann, D. Ghent, J. Remedios, P. North, C. Merchant, M. Berger, P.P. Mathieu, F.-M. Göttsche, Synergistic use of MERIS and AATSR as a proxy for estimating Land Surface Temperature from Sentinel-3 data, Remote Sensing of Environment, Volume 179, 2016, Pages 149-161, ISSN 0034-4257, http://dx.doi.org/10.1016/j.rse.2016.03.035.
(http://www.sciencedirect.com/science/article/pii/S0034425716301158)
Keywords: Land Surface Temperature; MERIS; AATSR; OLCI; SLSTR; Sentinel 3

OVERVIEW OF EXERCISE

1. OLCI L1 radiance to reflectance
2. Collocate OLCI-L1+ OLCI L2
3. Emissivity calculation based on NDVI /OGVI thresholds method →using band math (8 steps)
4. Water vapour band selection
5. Collocate SLSTR (master) / OLCI (slave) →from 300 m to 1000 m pixel
6. Apply the LST split window algorithm with the band math tool only on valid pixels → definition of "valid pixel" using masks and flags of the products
7. Validate with simulated in situ data: import of csv file, correlative plots, pixel information extraction demo
8. Comparison with S3 LST standard product using scatter plots
9. Batch processing: how to apply the processing chain to a bunch of products

1. RADIANCE TO REFLECTANCE

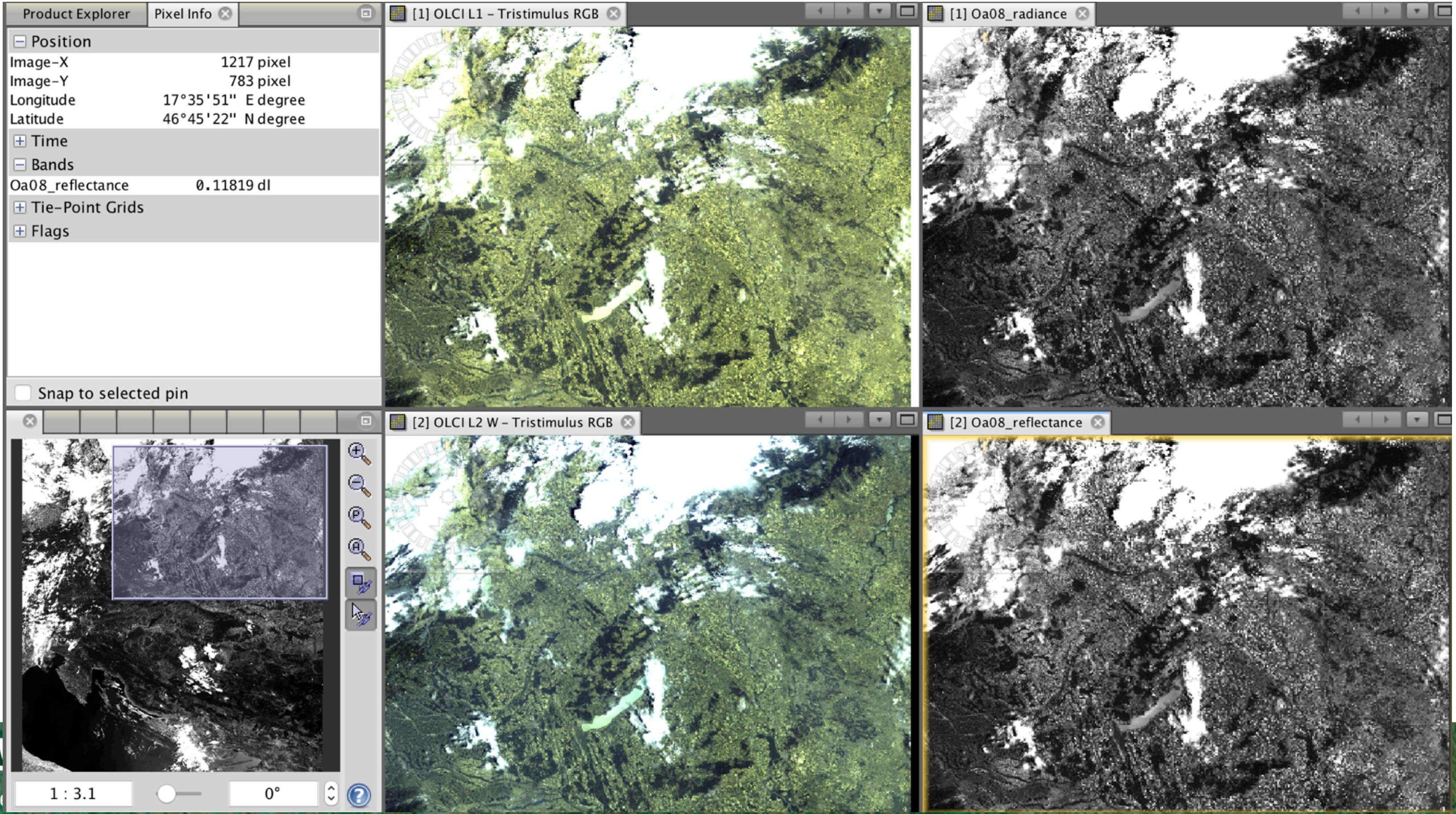
Open the scene:
"subset_0_of_S3A_OL_1_EFR____20170710T093144_20170710T093444_20170711T134744_0179_019_364_2159_LN1_O_NT_002.dim"

Right click on the product in the Product Explorer and select "`Open RGB Image Window`". Stretch the histogram for a better visualization in the "`Colour Manipulation`" window.

In the `Optical` label click on `Preprocessing/Radiance-to-Reflectance Processor`:

$$R_{TOA}(\lambda) = \frac{\pi \, L_{TOA}(\lambda)}{E_0(\lambda)\cos(\theta)}$$

1. RADIANCE TO REFLECTANCE



2. OLCI L1/L2 COLLOCATION

Use layer stacking to group the “*radrefl*” L1 and L2 OLCI bands in one product with the same spatial resolution and geo-location:

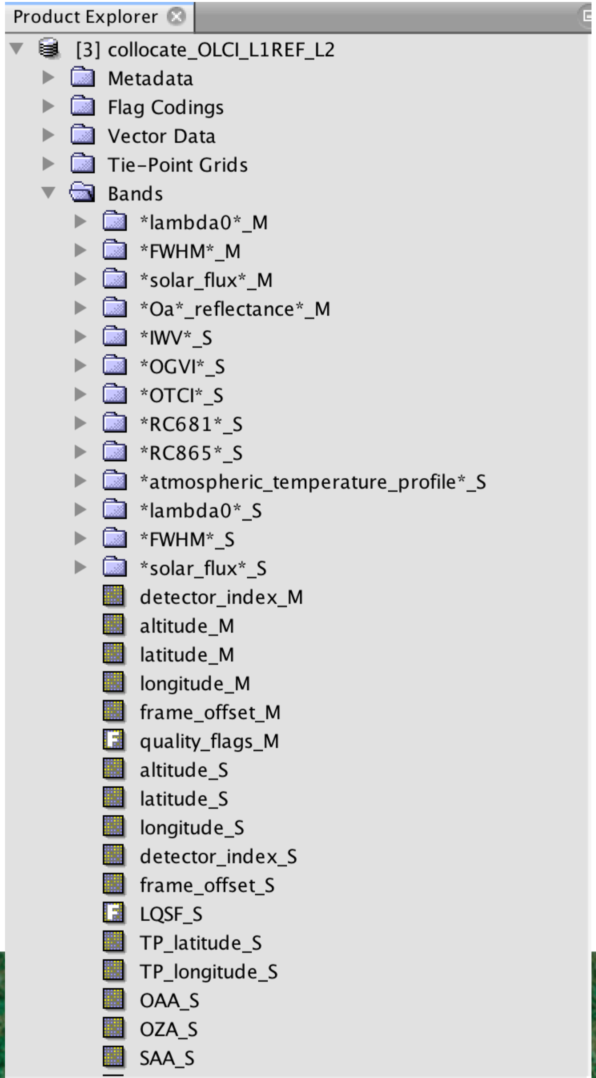
`Raster/Geometric Operations/Collocation`

Master file:

subset_0_of_S3A_OL_1_EFR____20170710T093144_20170710T093444_20170711T134744_0179_019_364_2159_LN1_O_NT_002_radrefl.dim

Slave file:

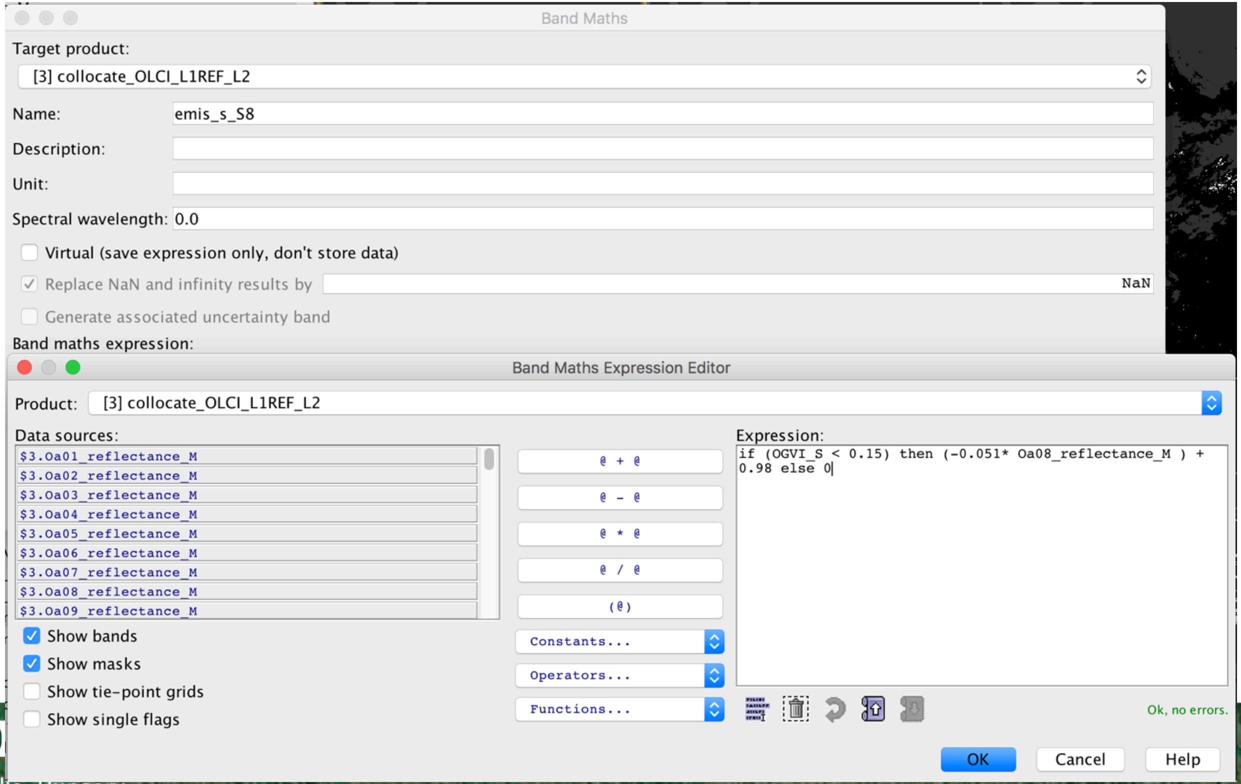
subset_1_of_S3A_OL_2_LFR____20170710T093144_20170710T093444_20170711T140642_0179_019_364_2159_LN1_O_NT_002.dim



3. EMISSIVITY FROM VEGETATION INDICES

Using the collocated product, start calculating the several variables needed for the LST algorithm.

`Raster/Band Maths`



Definition of emissivity

The emissivity, ϵ, at a given wavelength λ (units, μm) and temperature *T* (units, K), is defined as the ratio of the radiance $R_\lambda(T)$ emitted by a body at temperature *T* and the radiance $B_\lambda(T)$ emitted by a black body at the same temperature *T*, that is,

$$\varepsilon_\lambda(T) = \frac{R_\lambda(T)}{B_\lambda(T)}, \quad (1) \quad (1)$$

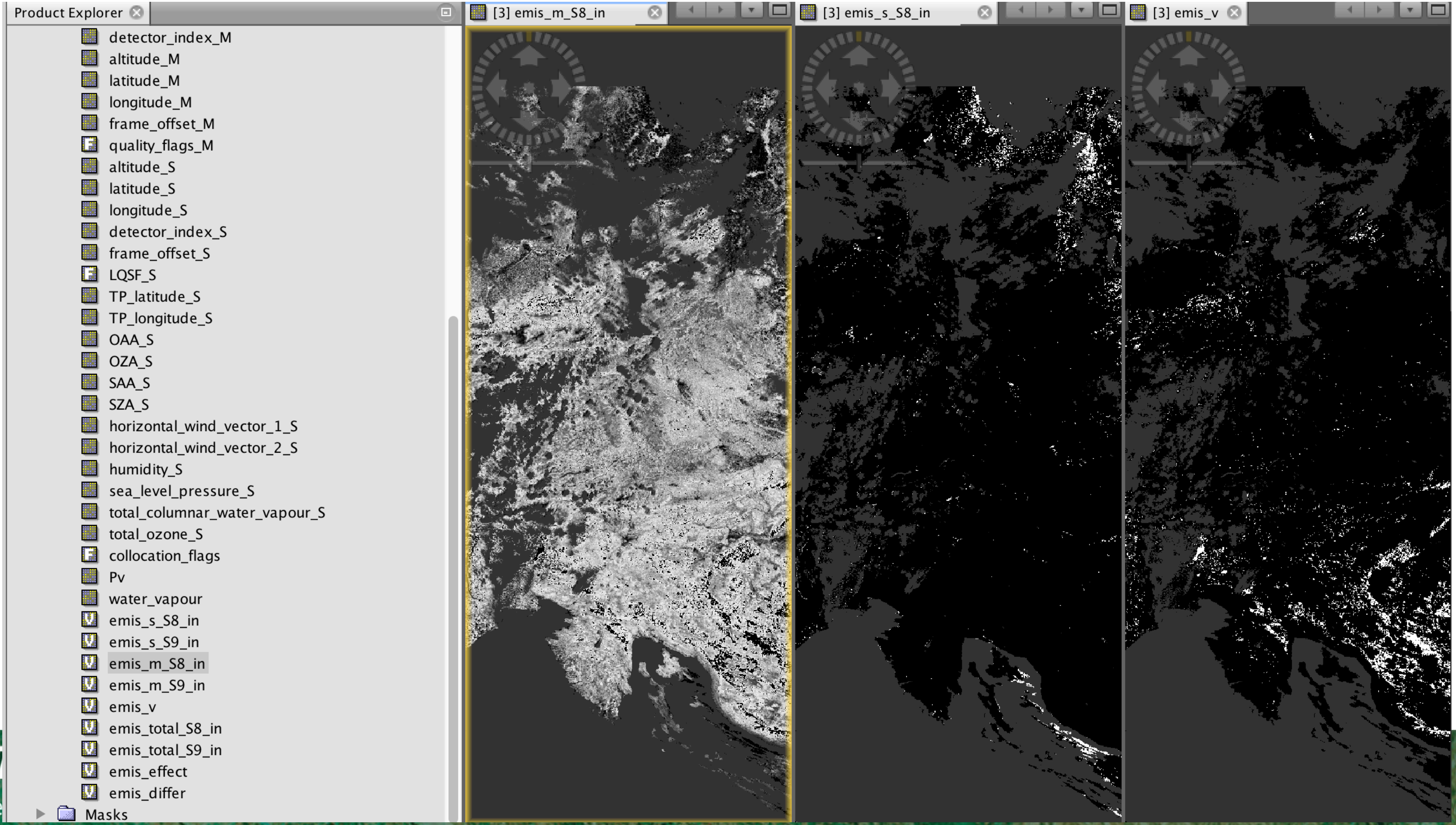
where $B_\lambda(T)$ refers to Planck's law, which is defined as

$$B_\lambda(T) = \frac{C_1\lambda^{-5}}{\exp(C_2/\lambda T) - 1}, \quad (2) \quad (2)$$

in which C_1 and C_2 are constants ($C_1 = 1.191 \times 10^8$ W μm^4 sr^{-1} m^{-2}, $C_2 = 1.439 \times 10^4$ μm K).

Land surface emissivity retrieval from satellite data
Li et al., 2013, IJRS, http://dx.doi.org/10.1080/01431161.2012.716540

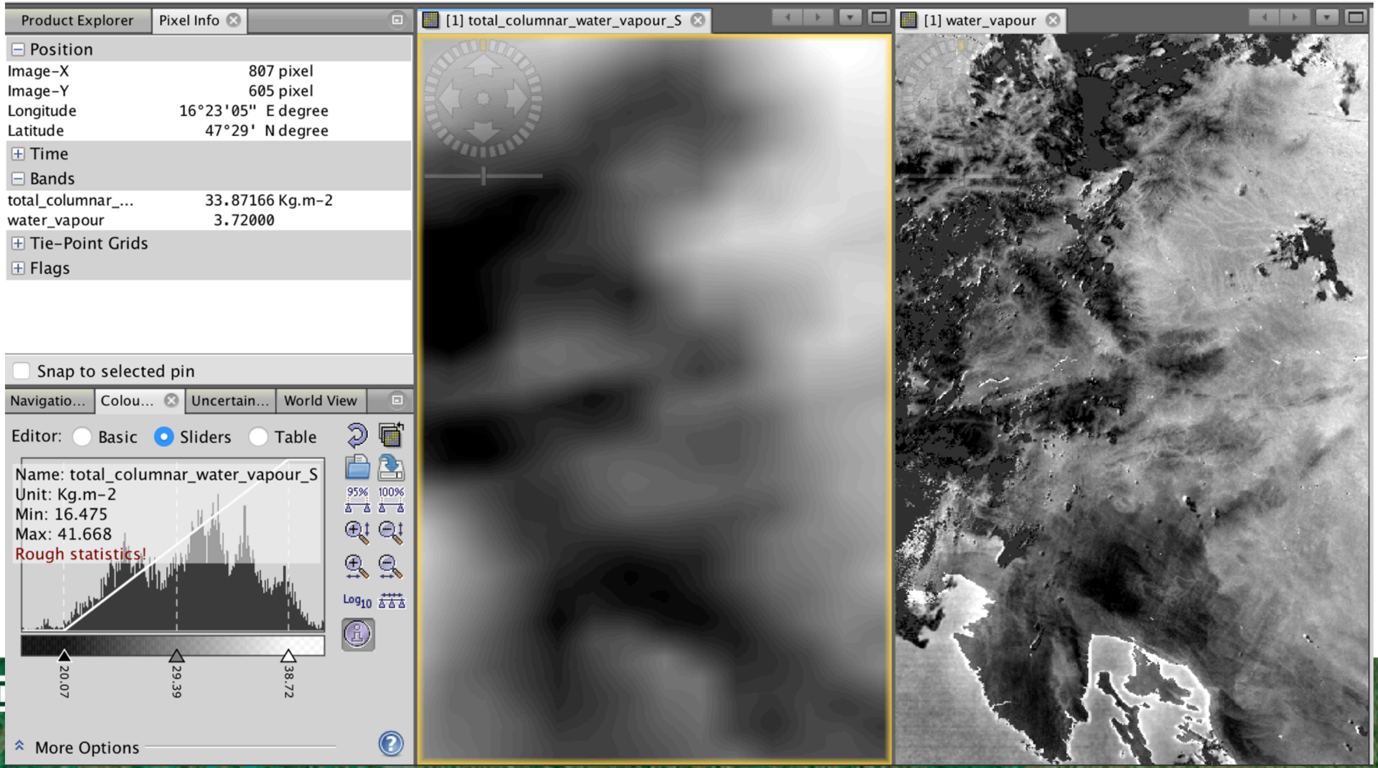
3. EMISSIVITY FROM VEGETATION INDICES



```
Pv
(OGVI - 0.15) / (0.9 - 0.15)

Soil emissivity
emis_s_S8_in = if (OGVI < 0.15) then (-0.051* reflec_band8_OLCI) + 0.98 else 0
emis_s_S9_in = if (OGVI < 0.15) then (-0.032* reflec_band8_OLCI) + 0.983 else 0


Mixed vegetation emissivity
emis_m_S8_in = if (OGVI > 0.15) and (OGVI < 0.99) then 0.969 *(1- Pv) + (.99*Pv)
else 0
emis_m_S9_in = if (OGVI > 0.15) and (OGVI < 0.99) then 0.977 *(1- Pv) + (.99*Pv)
else 0

Vegetation emissivity
emis_v = if (OGVI >0.99) then 0.99 else 0

Total emissivity
emis_total_S8_in = if (emis_s_S8_in !=0) or (emis_m_S8_in !=0) then
(emis_s_S8_in + emis_m_S8_in) else NaN
emis_total_S8_in = if (emis_s_S9_in !=0) or (emis_m_S9_in !=0) then
(emis_s_S9_in + emis_m_S9_in) else NaN

Effective emissivity
emis_effect = emis_total_S8_in + emis_total_S9_in / 2

Differential emissivity
emis_diff = emis_total_S8_in - emis_total_S9_in

Water vapour to g*cm2
water_vapour = IWS_S /10
```

4. WATER VAPOUR BAND SELECTION

Take the IWV (Integrated Water Vapour) band of OLCI L2 and pass from Kg/m² to g/cm² using Band Maths: `IWV/10`



5. SLSTR-OLCI COLLOCATION

Use layer stacking to group the SLSTR and OLCI bands in one product with the same spatial resolution (1km) and geo-location:

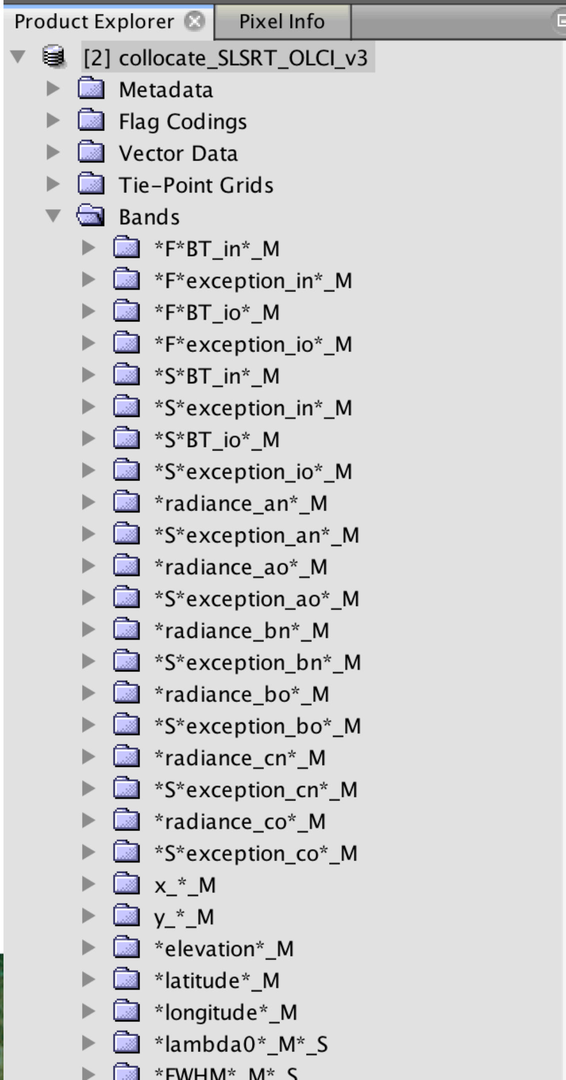
`Raster/Geometric Operations/Collocation`

`Master file:`

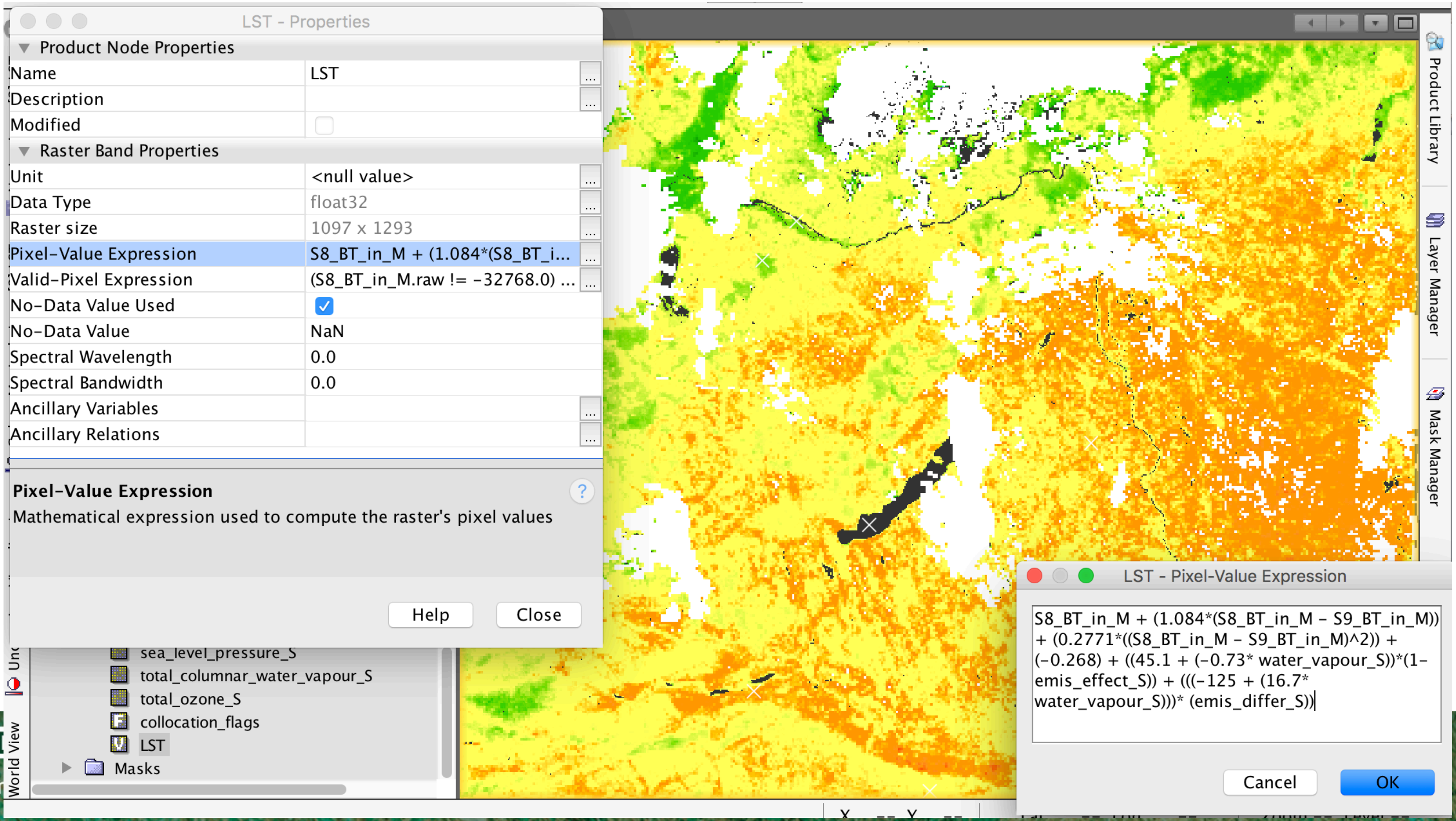
subset_2_of_S3A_SL_1_RBT____20170710T093144_20170710T093444_20170711T141258_0179_019_364_2159_LN2_O_NT_002.dim

`Slave file:`

collocate_OLCI_L1REF_L2.dim

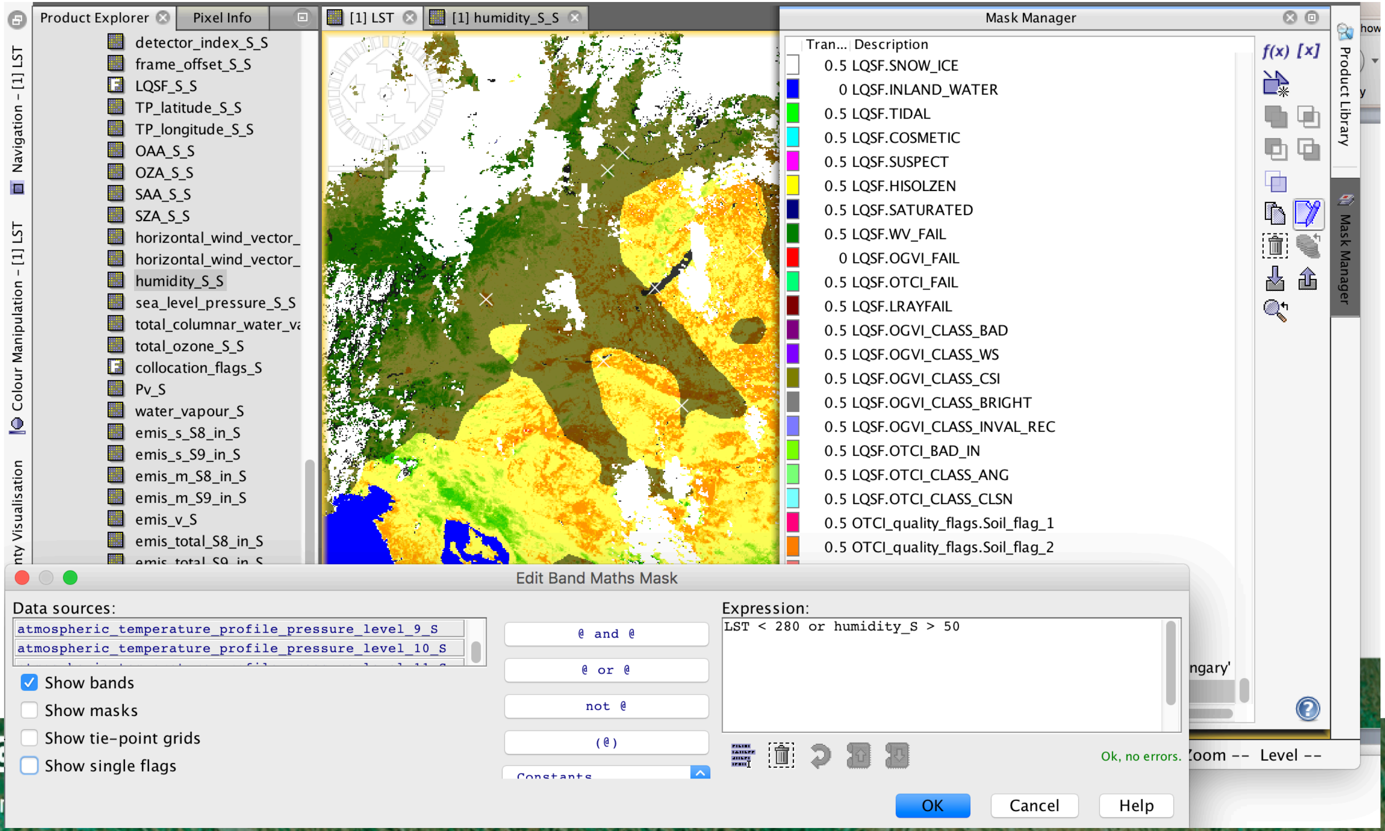


6. THE SPLIT WINDOW ALGORITHM



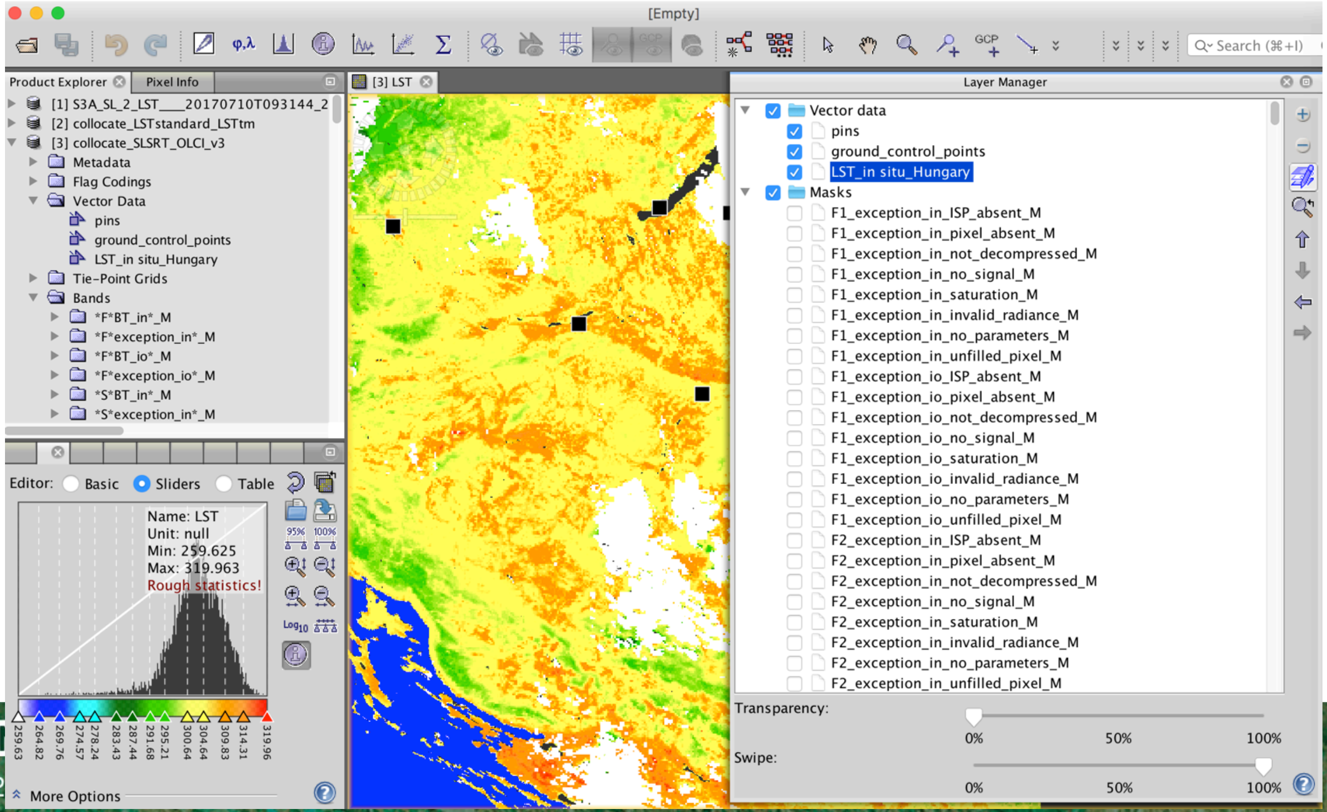
6. FLAGS AND MASKS

- Use the Mask Manager to visualize, change and created new masks from flags or bands.



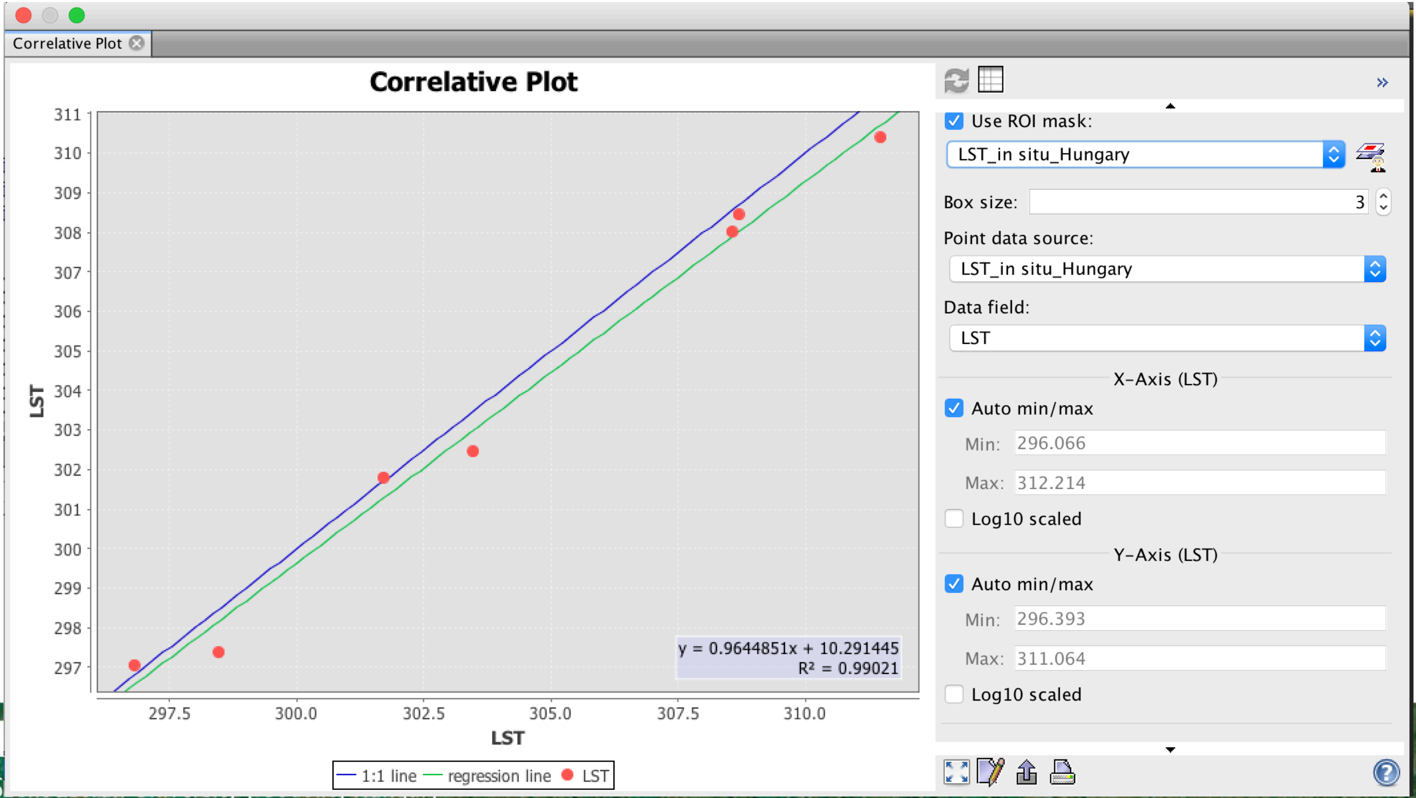
7. VALIDATION TOOLS: USING IN SITU DATA

1. Import file with in situ data: `File/Import/Vector Data/Vector from CSV`



7. VALIDATION TOOLS: USING IN SITU DATA

2. Make correlative plot: `Analysis/Correlative plot`



8. COMPARISON WITH OTHER PRODUCTS

Comparison of LST product with LST standard product:

1. Collocate products using `Raster/Geometry Operations/Collocation`:

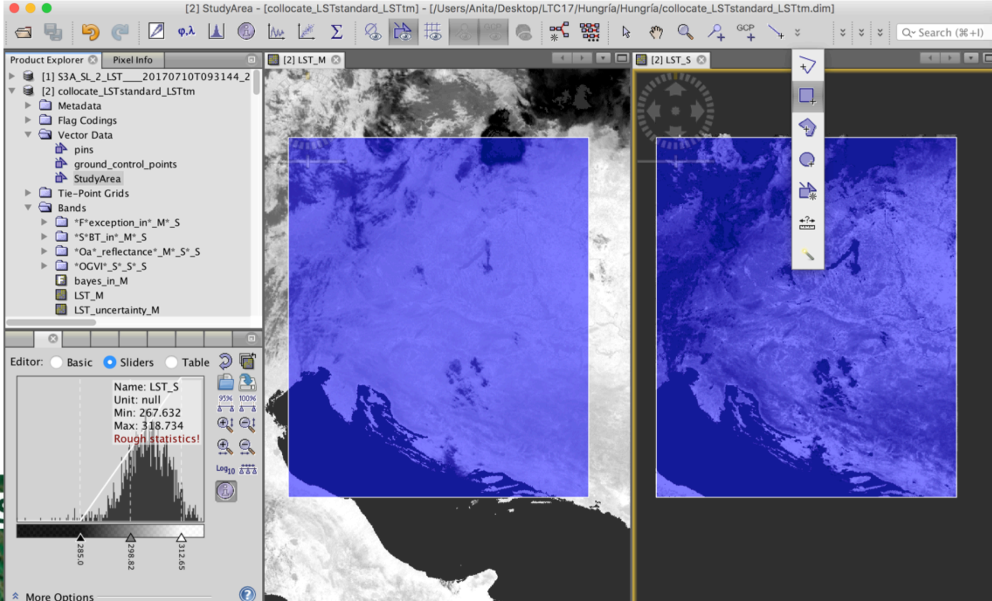
    Master product:

    subset_1_of_S3A_SL_2_LST____20170710T093144_20170710T093444_20170710T113909_0179_019_364_2159_SVL_O_NR_002.SEN3

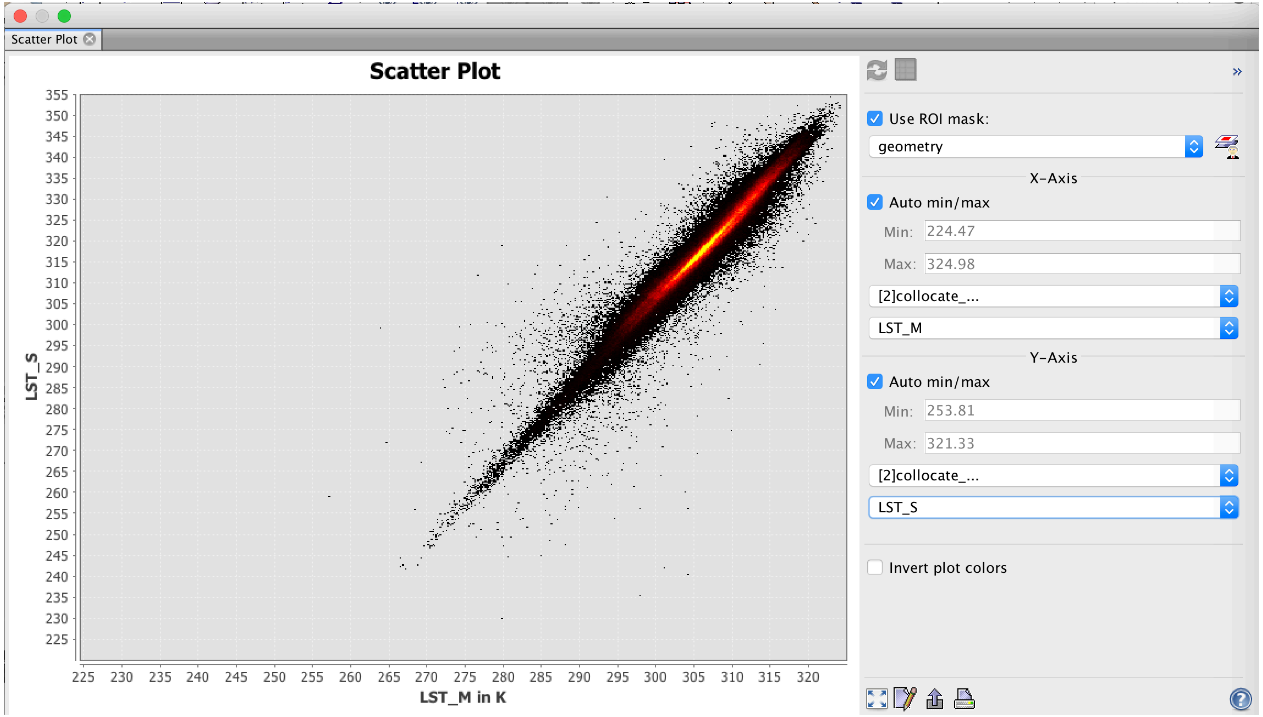
    Slave product: ***subset_0_of_collocate_SLSRT_OLCI_v3.dim***

2. Mask study are with geometry tools:

`Vector/New Vector Data Container`

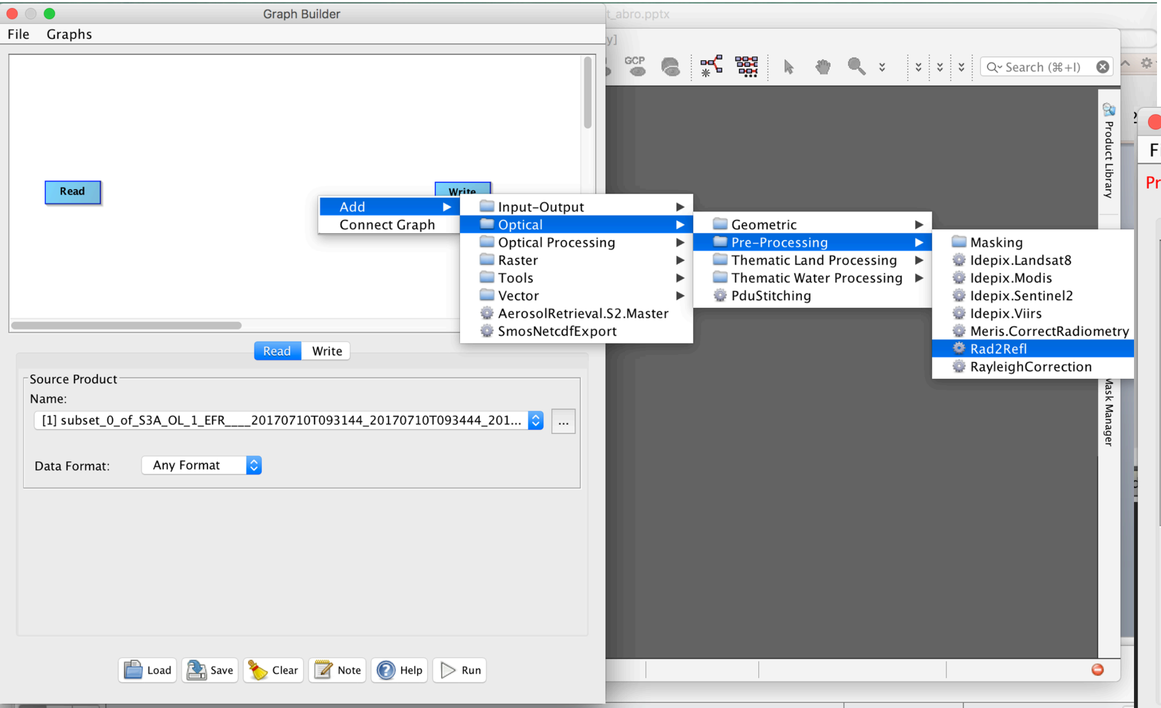


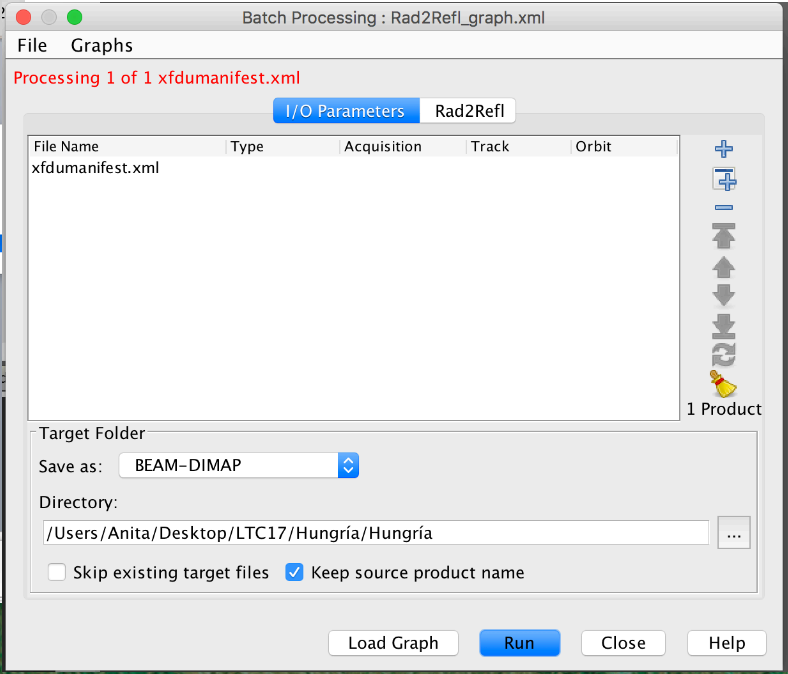
8. SCATTER PLOT
of both bands using the mask of the study area



9. PREPARING FOR BATCH PROCESSING

Tools/Graph Builder





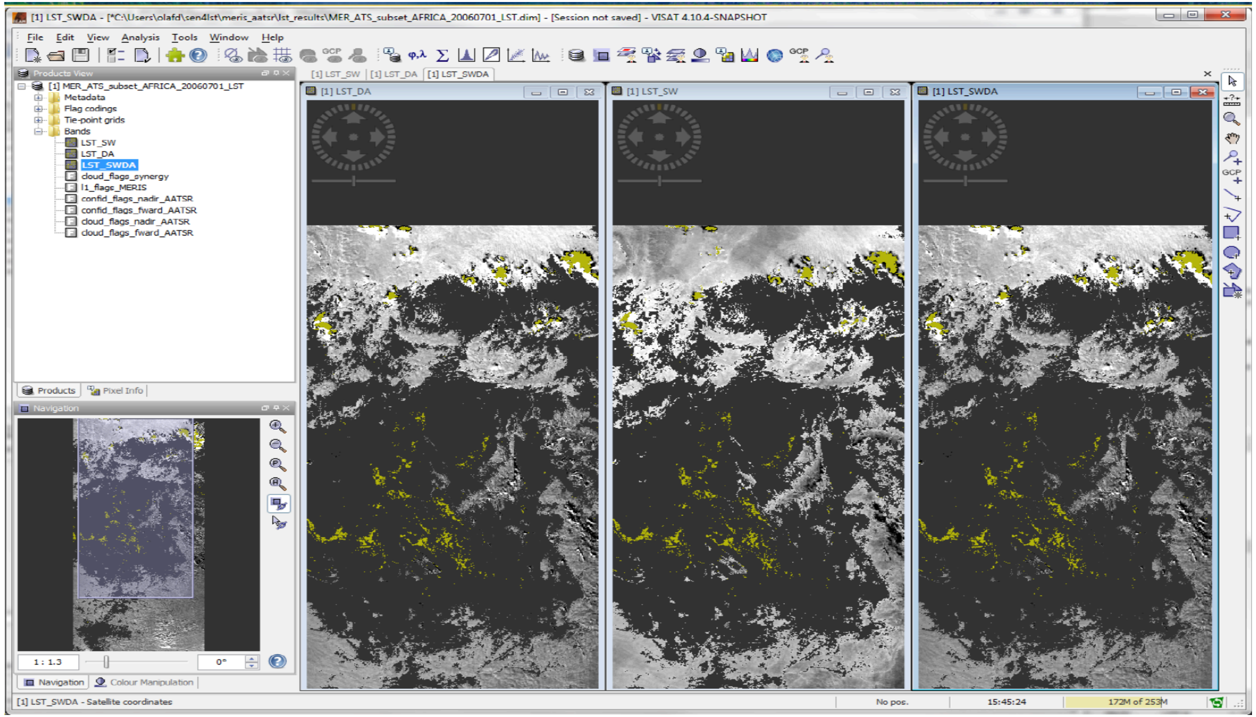
SEN4LST processor in BEAM-VISAT

- Synergistic Use of the Sentinel Missions for Estimating and Monitoring Land Surface Temperature
- 2014 ESA Support to Science Element Project
  - Univ. Valencia
  - Brockmann Consult GmbH
  - Univ. Swansea
- Project objectives:
  - **Development of an improved LST retrieval concept** for the Sentinel-2 and Sentinel-3 missions, including its validation with a detailed analysis of the spectral, spatial and temporal synergistic aspects provided by the Sentinel-2 and Sentinel-3 mission
  - **Adaptation and BEAM 4.11 implementation of the algorithm** to Envisat MERIS and AATSR data followed by a detailed assessment based on multi-temporal LST analysis and comparison with the standard AATSR LST product

LST processor specifications

- 2 Processor modules
  - Synergy Surface Directional Reflectance (SDR) retrieval including atmospheric correction and cloud screening
  - LST retrieval using split-window (SW), dual-angle (DA) and a combined (SW-DA) algorithm
- Input
  - Overlapping L1B products (MERIS/AATSR or simulated OLCI-SLSTR)
- Outputs
  - (Synergy SDR)
  - Three LST products for SW, DA, SW-DA

Example of several LST algorithms of the Sen4LST sensor



TAKE HOME MESSAGE

- Overview on Sentinel-3 OLCI and SLSTR sensors, including synergy products and applications
- Overview of SNAP Sentinel-3 Toolbox
- Exercise of Land Surface Temperature Calculation using the Vegetation Threshold Method
- Training using validation data and tools
- Introduction on batch processing
- Example of products from the SEN4LST processor in BEAM