INFORM overview

Ils REUSEN, VITO (ils.reusen@vito.be)

GEO AquaWatch Meeting

June 8-10 2016

Koblenz, Germany

VITO in numbers

- 750 employees
- 26 nationalities

- More than 400 patents worldwide

- HQ in Mol, Belgium. Offices in Ostend, Berchem, Ghent, Genk
- Subsidiary in China

- 200 scientific articles in 2014

- 1000 research projects

- 140 mio € turnover in 2014

- More than 500 research partners

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VITO Remote Sensing

Platforms

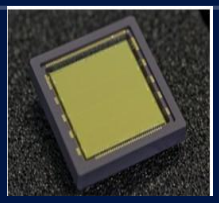

UAV

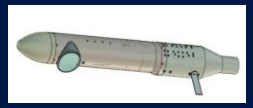

AIRBORNE

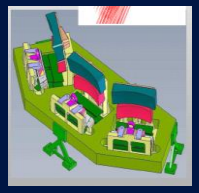

HALE UAV


SATELLITE

Sensors







Value Added Services & Information Products

Markets

Vegetation

Agriculture

Water

Forest

Environment & Security

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vito Copernicus

Improved monitoring and forecasting of ecological status of European INland waters by combining Future earth ObseRvation data and Models

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EU FP7-SPACE project INFORM

- Collaborative project - THEME [SPA.2013.1.1-07] [Remote sensing methods]
- Start date: 1/1/2014
- Duration: 48 months
- 9 beneficiaries from 7 EU Member States
- Requested EU contribution: € 1 991 902. 97
- Grant agreement n° 606865

INFORM partners

	Participant organisation name	Participant short name	Country
vito vision on technology	VLAAMSE INSTELLING VOOR TECHNOLOGISCH ONDERZOEK N.V.	VITO - Coordinator	BELGIUM
istituto per il rilevamento elettromagnetico dell'ambiente	CONSIGLIO NAZIONALE DELLE RICERCHE	CNR	ITALY
EOMAP	EOMAP GmbH & Co.KG	EOMAP	GERMANY
UNIVERSITY OF STIRLING	THE UNIVERSITY OF STIRLING	U STIRLING	UK
museum OD Nature I OD Natuur I DO Nature	INSTITUT ROYAL DES SCIENCES NATURELLES DE BELGIQUE	RBINS	BELGIUM
Deltares	STICHTING DELTARES	Deltares	THE NETHERLANDS
PML Plymouth Marine Laboratory	PLYMOUTH MARINE LABORATORY	PML	UK
MTA ÖKOLÓGIAI KUTATÓKÖZPONT Centre for Ecological Research	MAGYAR TUDOMANYOS AKADEMIA OKOLOGIAI KUTATOKOZPONT	MTA OK	HUNGARY
	KLAIPEDOS UNIVERSITETAS	KLAIPEDOS UNIVERSITETAS	LITHUANIA

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Main objectives

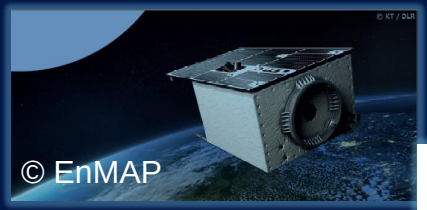
- To **develop and demonstrate** new and improved user-driven **products for inland water quality** monitoring and forecasting by combining **water quality models** and **EO data which fully exploits the improved spectral, spatial and temporal capabilities of new and upcoming EO missions** like Sentinel-2, Sentinel-3 and hyperspectral EO missions like EnMAP and PRISMA.
- To **provide recommendations** for future EO missions taking into account requirements for inland water quality monitoring.

Update on satellite missions

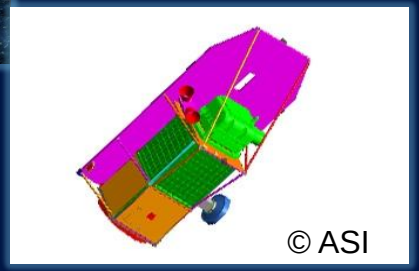
- Sentinel-2 (launched 23 June 2015, images available)

- Sentinel-3 (launched 16 February 2016; in commissioning phase)

- EnMAP (2017-2018?)



- PRISMA (2017-2018?)



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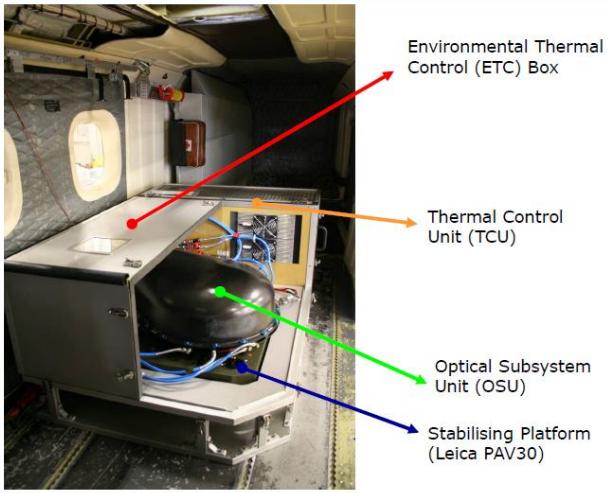
Sentinel-2

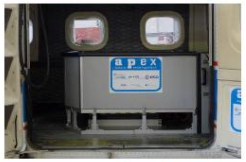
- Sentinel-2A launched: June 2015
- Global revisit time: 5 days with 2 satellites
- MSI (Multi Spectral Instrument)
  - 13 spectral bands: 443 nm– 2190 nm (including 3 bands for atmospheric corrections)
  - Spectral resolution: 15 nm– 180 nm
  - Spatial resolution: 10 m, 20 m and 60 m
  - Swath: 290 km

Sentinel-3

- Sentinel-3A launched Feb 2016
- 2 day global coverage
- OLCI (Ocean and Land Colour Instrument)
  - Swath width: 1270 km, with 5 tilted cameras
  - Spatial sampling: 300 m (full resolution mode)
  - Spectral range: 21 bands [0.4-1.02] µm

APEX system overview





APEX airborne hyperspectral imaging sensor for

- Simulation
- Calibration
- Validation

of satellite sensors/products

http://www.apex-esa.org

Parameter	Value
Field of View (FOV) – pushbroom technique	Swath: ± 14deg with 1000 across-track pixel
Instantaneous Field of View (IFOV)	0.028 deg
Flight altitude range	3,500 – 10,000 m.a.s.l.
Standard aircraft interface	for Dornier Do-228 on stabilizing platform PAV-30
Spectral range	VNIR: 380 – 1000 nm, SWIR: 940 – 2500 nm
Spectral channels	VNIR: 312 (prior binning), SWIR: 199
Spectral sampling interval	380 – 1050 nm: < 5 nm, 1050 – 2500 nm: < 10 nm
Center wavelength accuracy	< 0.2 nm
PSF (Point Spread Function)	≤ 1.75 Sampling interval
Spectral / Spatial Misregistration	< 0.1 pixel
Polarization sensitivity	Less 0.03 in VNIR, Less 0.05 in SWIR (goal)
Spatial co-registration between VNIR and SWIR channel	Goal: 0.16 pixel
Instrument temporal radiometric uncertainty within a flight section	Better 0.02
Interval for instrument re-calibration	After a complete flight season
Radiometric performance accuracy	Instrument shall allow absolute calibration accuracy up to 0.03 (goal)

S2, S3, EnMAP, PRISMA with improved spectral, spatial and temporal capabilities

End-user needs (WFD, Dredging industry)

OUTLOOK: Inland Water Quality services

Recommendations for future EO missions for Inland Water Quality monitoring

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European approach

Site	Country	Characteristic
Lake Balaton	Hungary	Largest lake in Central Europe, shallow and meso-eutrophic
Kis-Balaton	Hungary	Hypereutrophic water reservoir system
Curonian lagoon	Lithuania	Hypereutrophic coastal lagoon
Mantua Lakes	Italy	Small and shallow artificial eutrophic basins
Lagoon of Venice	Italy	Turbid coastal lagoon
Lake Constance	Germany, Switzerland, Austria	Meso-oligotrophic lake
Lake Geneva (Lac Lémen)†	Switzerland, France	Meso-oligotrophic lake
Gironde river	France	Highly turbid river
Scheldt river	Belgium	Highly turbid river
Esthwaite Water	UK	Small, monomictic eutrophic lake
Loch Lomond	UK	Warm, monomictic; oligotrophic in northern basin, mesotrophic in southern basin
Loch Leven	UK	Shallow, polymictic eutrophic shallow lake
IJsselmeer	The Netherlands	Eutrophic, largest freshwater lake in northwestern Europe; Markermeer is a turbid lake.

Lake Geneva added after EUAB02 and gap analysis

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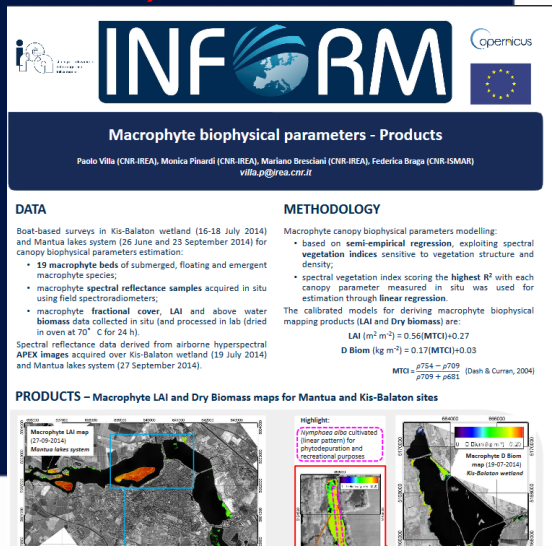
WP objectives

- WP1 Management (VITO)
  - Legal management
  - Financial management
  - Administrative management
- WP2 Scientific coordination (VITO)
  - Scientific coordination of the project
- WP3 End-user interaction (CNR)
  - To explore the end-user requirements in terms of water quality products
  - To stimulate project results' uptake by the end-users and industry
- WP4 Data gathering (VITO)
  - To inventory existing data, identify data gaps
  - To acquire new (in-situ, APEX hyperspectral and satellite) data
    - Development Campaign – 2014
    - Testing Campaign – 2016

WP objectives

- WP5 Algorithm development and validation (U STIRLING)
  - Development and validation of EO products, and estimation of their uncertainty for WP6
    - Atmospheric correction (RBINS)
    - Attenuation and euphotic depth (RBINS)
    - TSM and turbidity (VITO)
    - Yellow matter (PML)
    - Phytoplankton functional types (CNR)
    - Stratification (EOMAP)
    - Macrophytes (CNR)
    - Phytoplankton primary production (U STIRLING)
    - Sun-induced chlorophyll fluorescence (U STIRLING)

Status: see product flyers at http://www.copernicus-inform.eu/content/downloads ATBD (June 2016)



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Macrophyte biophysical parameters - Products

Paolo Villa (CNR-IREA), Monica Pinardi (CNR-IREA), Mariano Bresciani (CNR-IREA), Federica Braga (CNR-ISMAR)
villa.p@irea.cnr.it

DATA

Boat-based surveys in Kis-Balaton wetland (16-18 July 2014) and Mantua lakes system (26 June and 23 September 2014) for canopy biophysical parameters estimation:

- **19 macrophyte beds** of submerged, floating and emergent macrophyte species;
- macrophyte **spectral reflectance samples** acquired in situ using field spectroradiometers;
- macrophyte **fractional cover**, **LAI** and above water **biomass** data collected in situ (and processed in lab (dried in oven at 70° C for 24 h).

Spectral reflectance data derived from airborne hyperspectral **APEX images** acquired over Kis-Balaton wetland (19 July 2014) and Mantua lakes system (27 September 2014).

METHODOLOGY

Macrophyte canopy biophysical parameters modelling:

- based on **semi-empirical regression**, exploiting spectral **vegetation indices** sensitive to vegetation structure and density;
- spectral vegetation index scoring the **highest R^2** with each canopy parameter measured in situ was used for estimation through **linear regression**.

The calibrated models for deriving macrophyte biophysical mapping products (**LAI** and **Dry biomass**) are:

LAI ($m^2\ m^{-2}$) = 0.56(**MTCI**)+0.27

D Biom ($kg\ m^{-2}$) = 0.17(**MTCI**)+0.03

$MTCI = \frac{\rho 754 - \rho 709}{\rho 709 + \rho 681}$ (Dash & Curran, 2004)

PRODUCTS – Macrophyte LAI and Dry Biomass maps for Mantua and Kis-Balaton sites

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WP objectives

- WP6 EO-model integration (Deltares)
  - Integration of Earth Observation (EO) & In-Situ (IS) data and Water Quality (WQ) modelling

Workflow

Historic IS & EO data, hydrometeo inputs

T6.1 Initial setup of dynamic models

INFORM IS + EO data, dev. & test campaign

T6.3 2nd calibration, validation

T6.2 Methodology (VITO)

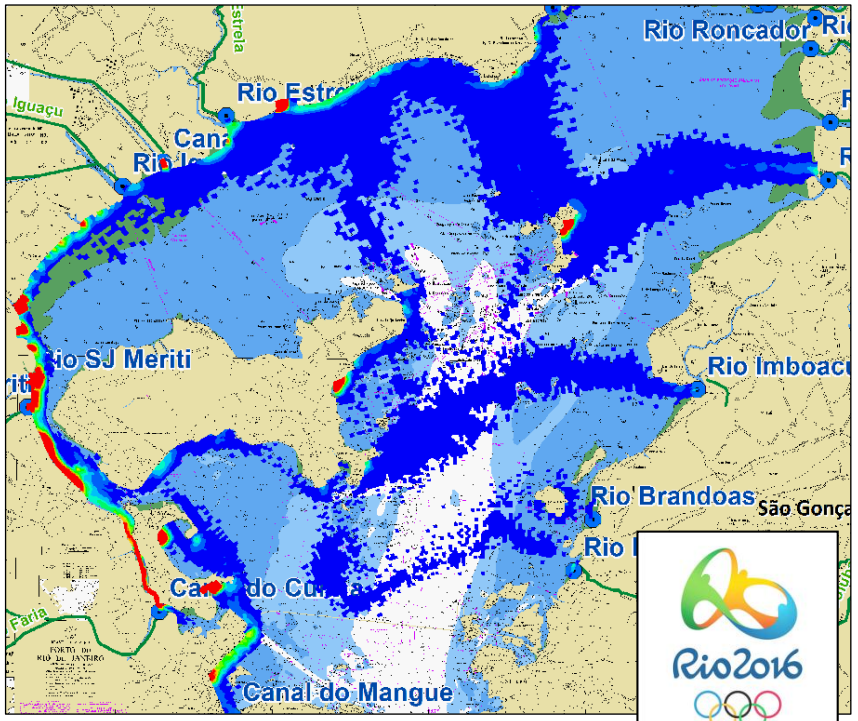
Historic & INFORM EO data

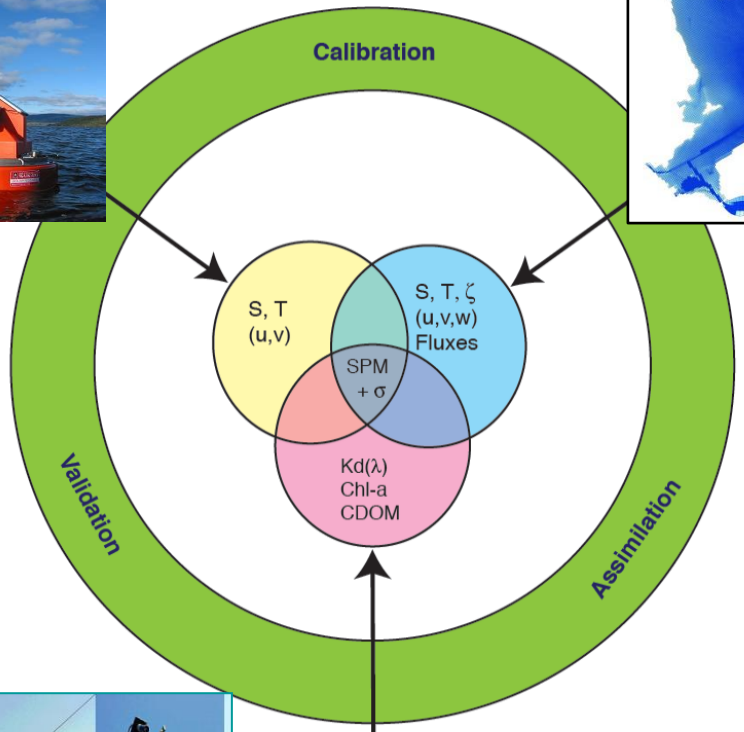
INFORM IS + EO data

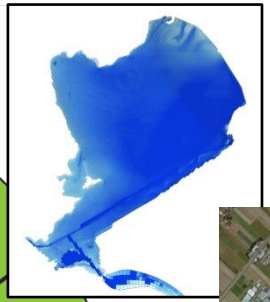
WP 7 Optimized calibration & forecast

Why model?

- Interpolation & reconstruction in time & space, historic trends, unobserved variables, fluxes
- Scenario studies, impact assessments
- Forecasting (NRT) of algal blooms, resuspension events & spills







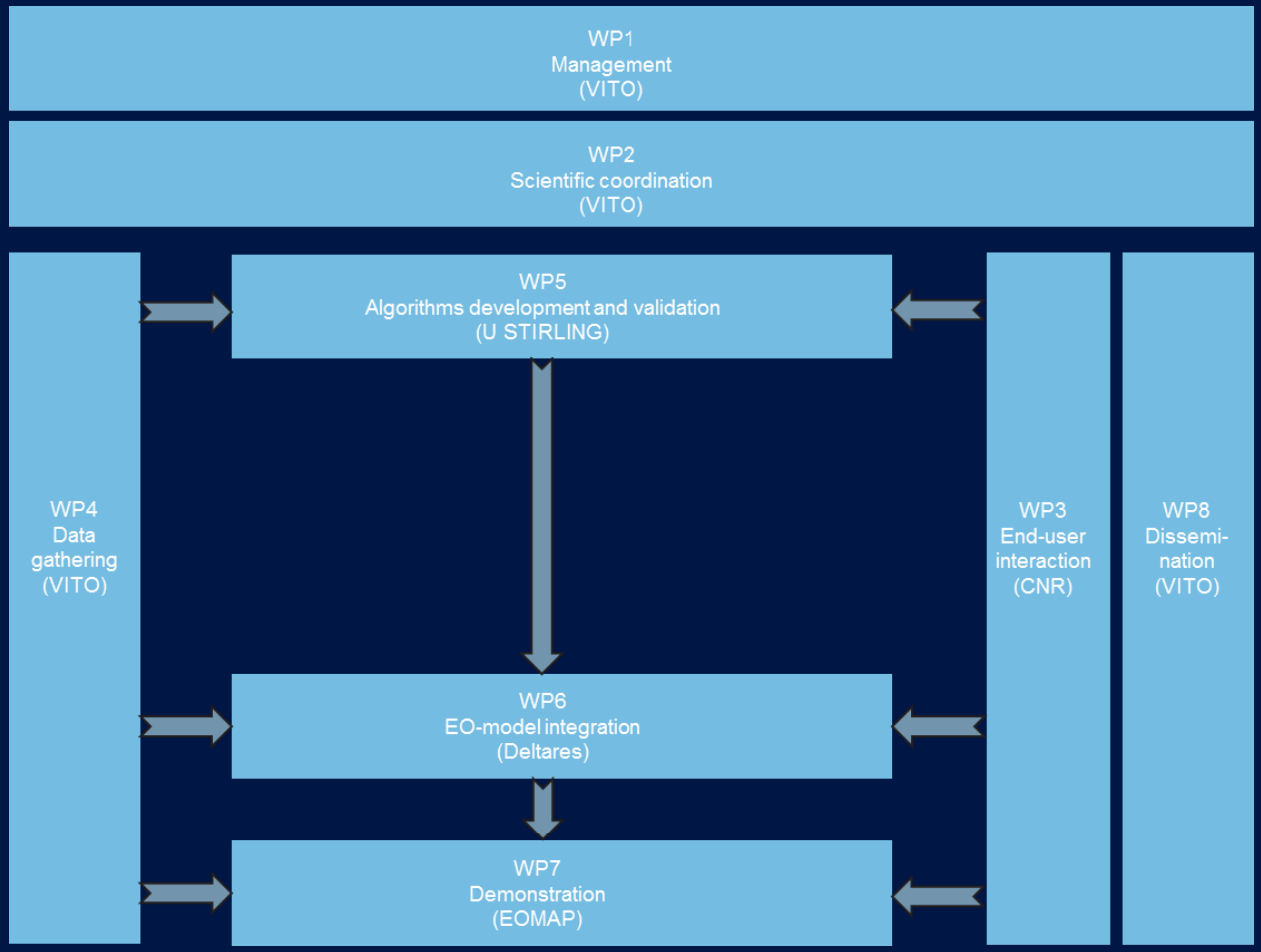
Modelling framework to relate sparse or piecemeal data sets to each other and to the system dynamics

data → information → insight by model context & structure

WP objectives

- WP7 Demonstration (EOMAP)
  - To demonstrate to end-users
    - the INFORM prototype algorithms applied to new satellite sensors and
    - the added value of INFORM EO products for WQ model validation and forecasting
  - To test the compliance of INFORM EO products with end-user requirements
- WP8 Dissemination (VITO)
  - To disseminate the project objectives, progress and results
  - To raise the awareness of the INFORM project
  - To give recommendations for future satellite missions
  - To organise a results uptake workshop

Interdependency of Work Packages



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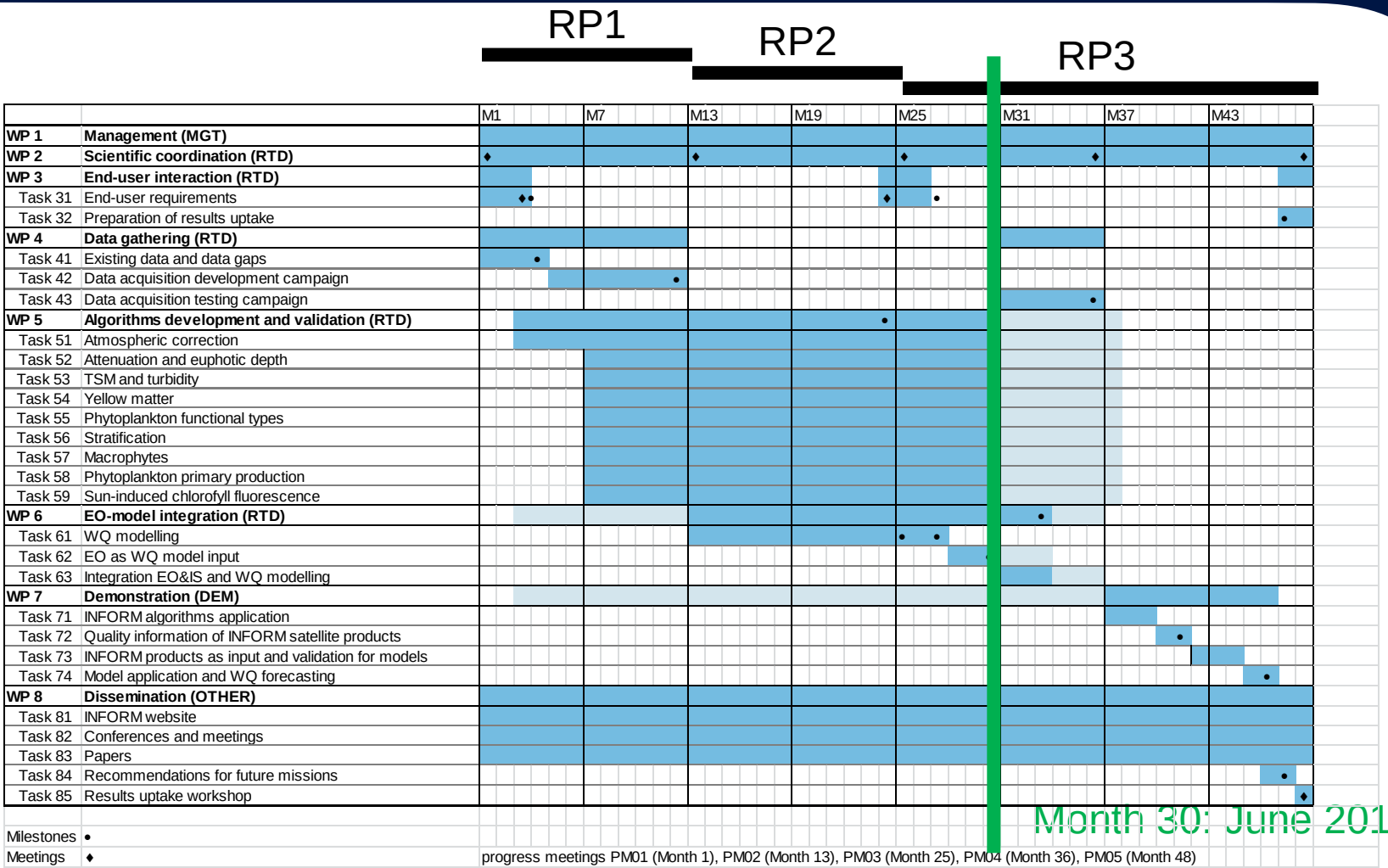

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INFORM website
http://www.copernicus-inform.eu

Papers

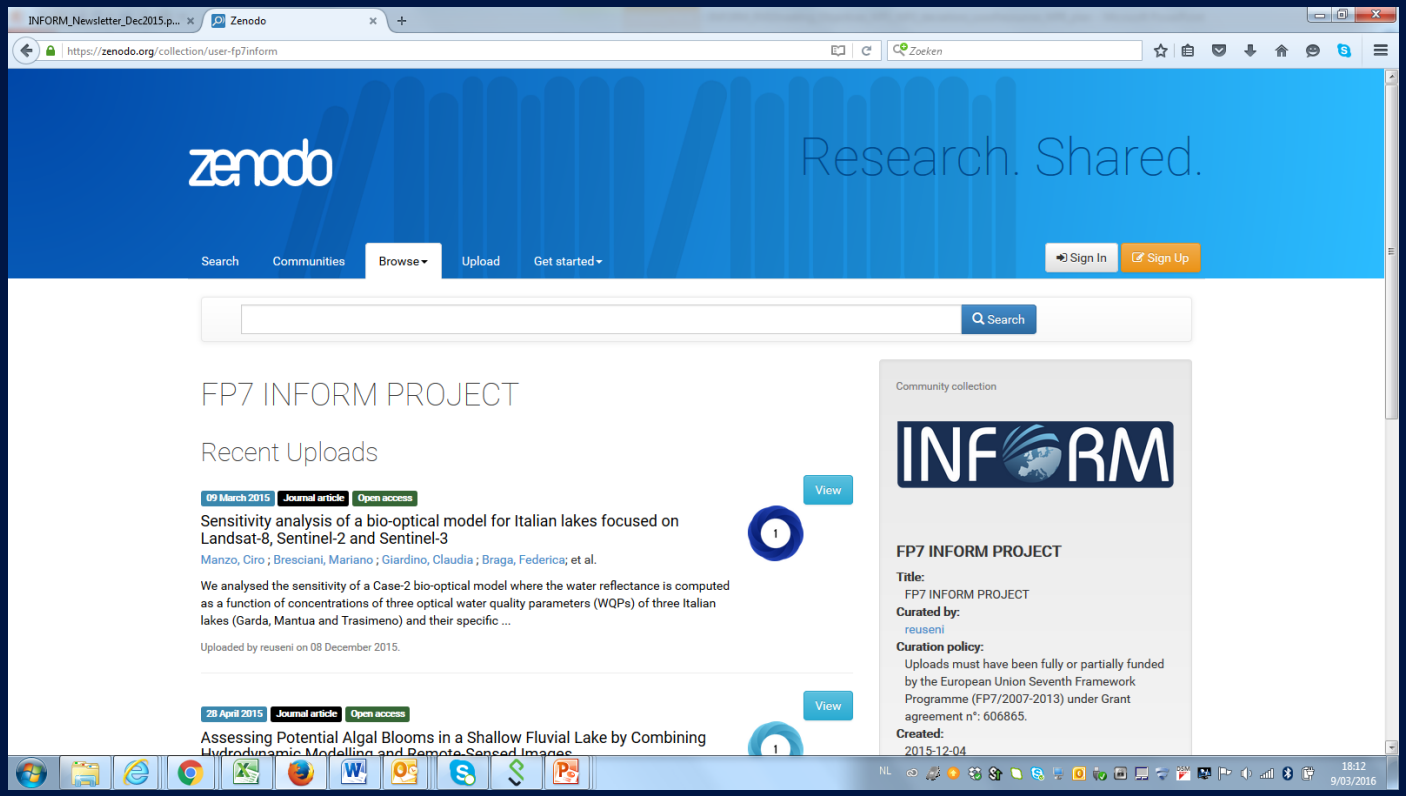
- Hestir E. L., Brando V. E., Bresciani M., Giardino C., Matta E., Villa P., Dekker A. G. (2015). **Measuring freshwater aquatic ecosystems: The need for a hyperspectral global mapping satellite mission**. Remote Sensing of Environment, 71: 218–233. doi.org/10.1016/j.rse.2015.05.023
- Knaeps E., Ruddick K.G., Doxaran D., Dogliotti A.I., Nechad B., Raymaekers D. , Sterckx S. (2015). **A SWIR based algorithm to retrieve total suspended matter in extremely turbid waters**. Remote Sensing of Environment, 168: 66–79. doi:10.1016/j.rse.2015.06.022
- Manzo C., Bresciani M., Giardino C., Braga F., Bassani C., (2015). **Sensitivity analysis of a bio-optical model for Italian lakes focused on Landsat-8, Sentinel-2 and Sentinel-3**. European Journal of Remote Sensing, 48: 17-32. doi:10.5721/EuJRS20154802
- Palmer S.C.J., Kutser T. and Hunter P.D. (2015). **Remote sensing of inland waters: challenges, progress and future directions**. Remote Sensing of Environment, Special Issue: Remote Sensing of Inland Waters, 157: 1–8. doi:10.1016/j.rse.2014.09.021

Papers

- Pinardi M., Fenocchi A., Giardino C., Sibilla S., Bartoli M., Bresciani M. (2015). **Assessing Potential Algal Blooms in a Shallow Fluvial Lake by Combining Hydrodynamic Modelling and Remote-Sensed Images**. Water, 7 (5): 1921-1942. doi:10.3390/w7051921
- Sterckx S., Knaeps E., Adriaensen S., Reusen I., De Keukelaere L., Hunter P., Giardino C., & Odermatt D. (2015). **Opera: An Atmospheric correction for land and water**. Published in the proceedings of the Sentinel-3 for Science Workshop held in Venice-Lido, Italy, 2-5 June 2015, ESA Special Publication SP-734.
- Vaičiūtė D., Bresciani M., Bartoli M., Giardino C., Bučas M. (2015). **Spatial and temporal distribution of coloured dissolved organic matter in a hypertrophic freshwater lagoon**. Journal of Limnology, 74(3): 572-583. doi:10.4081/jlimnol.2015.1176
- Van der Zande D. & Blaas M. & Nechad B. (2015). **Sensitivity Analysis of Semi-Analytical Models of Diffuse Attenuation of Downwelling Irradiance in Lake Balaton.** Published in the proceedings of the Sentinel-3 for Science Workshop held in Venice-Lido, Italy, 2-5 June 2015, ESA Special Publication SP-734.
- Villa P., Bresciani M., Bolpagni R., Pinardi M., Giardino C, (2015). **A rule-based approach for mapping macrophyte communities using multi-temporal aquatic vegetation indices**. Remote sensing of environment, 171: 218–233. doi:10.1016/j.rse.2015.10.020

ZENODO OPEN ACCESS papers

» ZENODO repository: https://zenodo.org/collection/user-fp7inform



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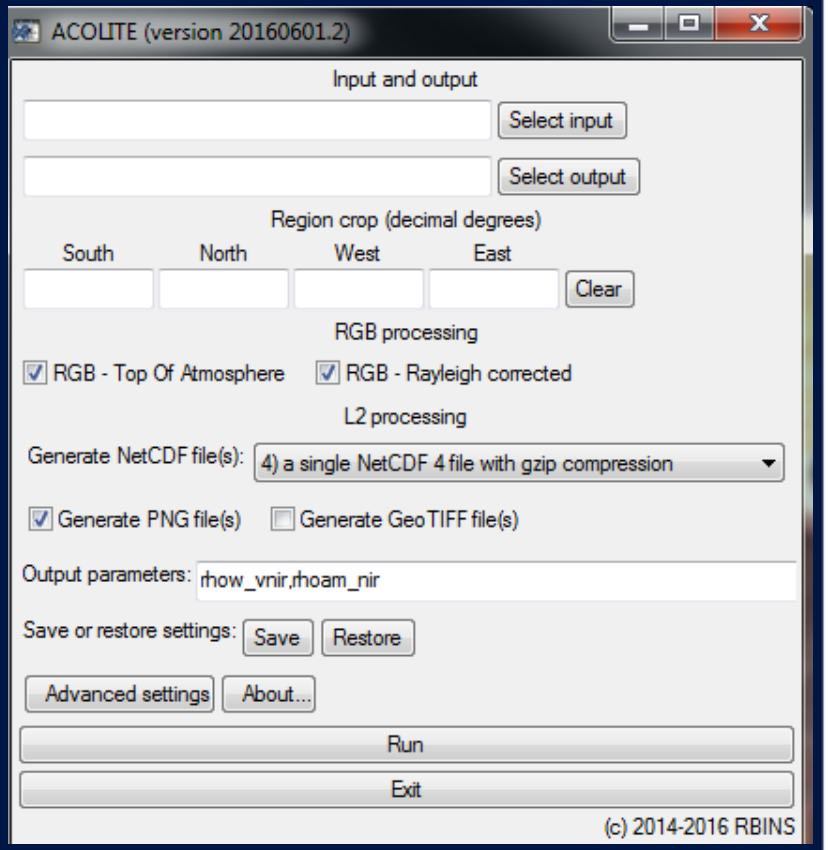
ACOLITE (RBINS)

Currently at version '20160601'

- Binary distribution of Landsat-8/Sentinel-2 AC processor for Windows, Linux and MAC
- Simple and fast processing of L8/S2 images for marine and inland water applications
- AC is image based, no need for external Inputs!!
- ε constant over scene (crop), aerosol multiple scattering reflectance varies per pixel



ACOLITE (RBINS)

Standard Features

- Atmospheric correction of **Landsat-8** and **Sentinel-2**
- RGB image generation (TOA, RCO, pan sharpened), RGB scaling
- extraction of rectangular regions
- L2 processing

→ products:

Rhow	**CHL_OC2, CHL_OC3**	**SPM_NECHAD 561, 655, 865**
RTOA, LTOA	**DEM**	**T_NECHAD_645**
RRC, LRC	**FAI (floating algae index)**	**T_DOGLIOTTI (red, NIR, mix)**
RHOAM	**NDVI, NDVI_TOA, NDVI_RCO**	**QAA_a QAA_bb QAA_Kd**

ACOLITE (RBINS)

Availability

Direct Download

https://odnature.naturalsciences.be/remsem/software-and-data/index

(or just google 'ACOLITE' → first hit)

OPERA-Atmospheric Correction Processor

OPERA

operational atmospheric correction for land and water

Macrophyte waters | Rivers and estuaries | High altitude lakes | Coastal waters | Land





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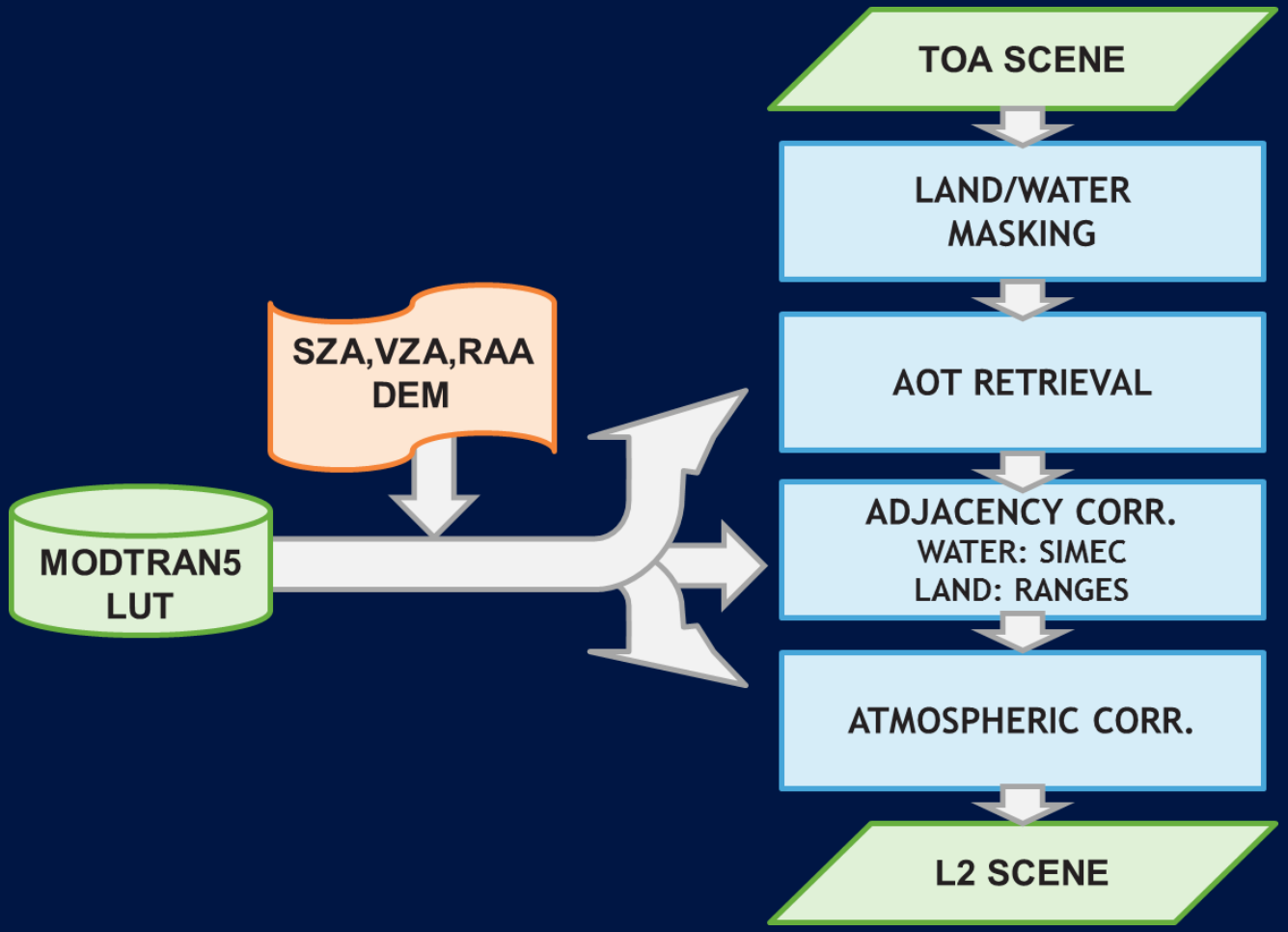
OPERA Workflow



Planned: OPERA Integration in Sentinel-2 Toolbox

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Highroc

http://www.highroc.eu

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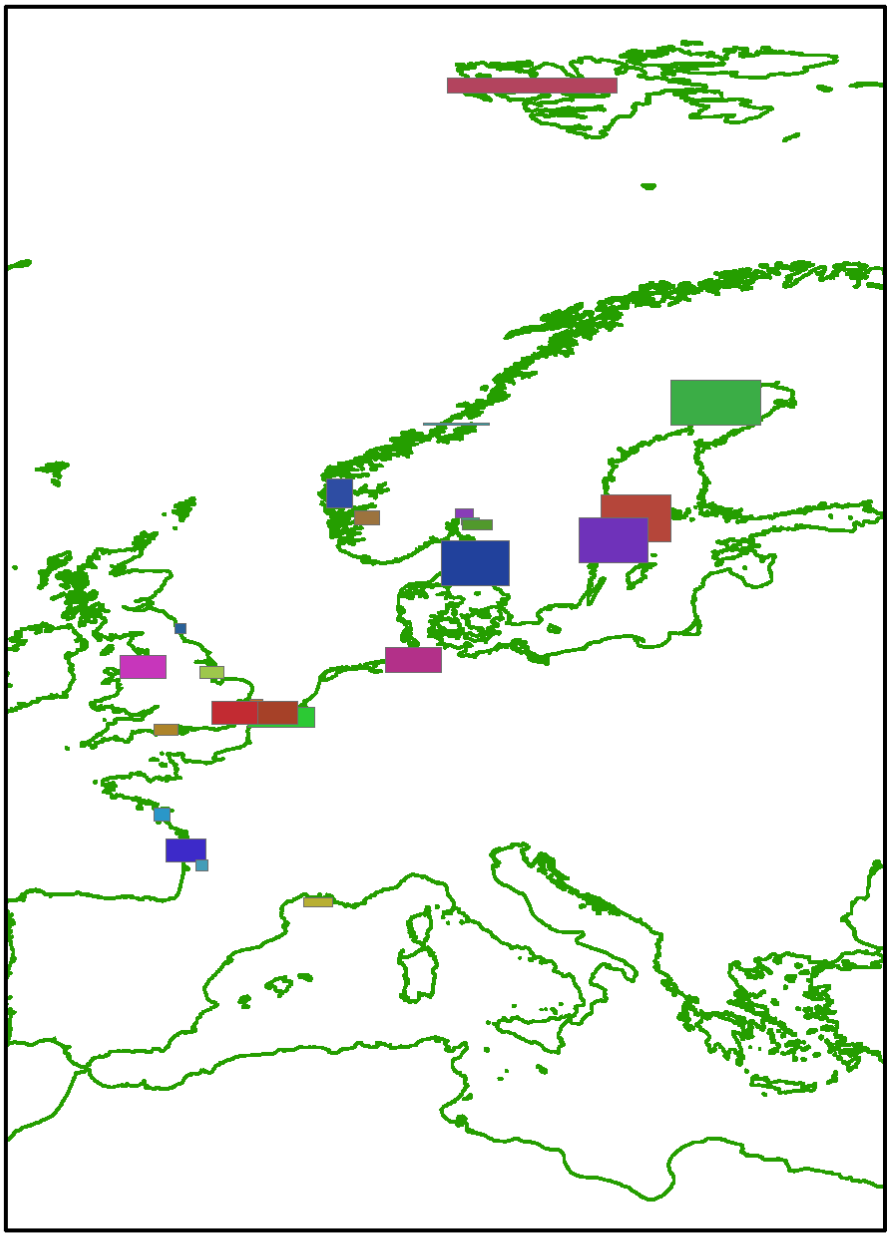
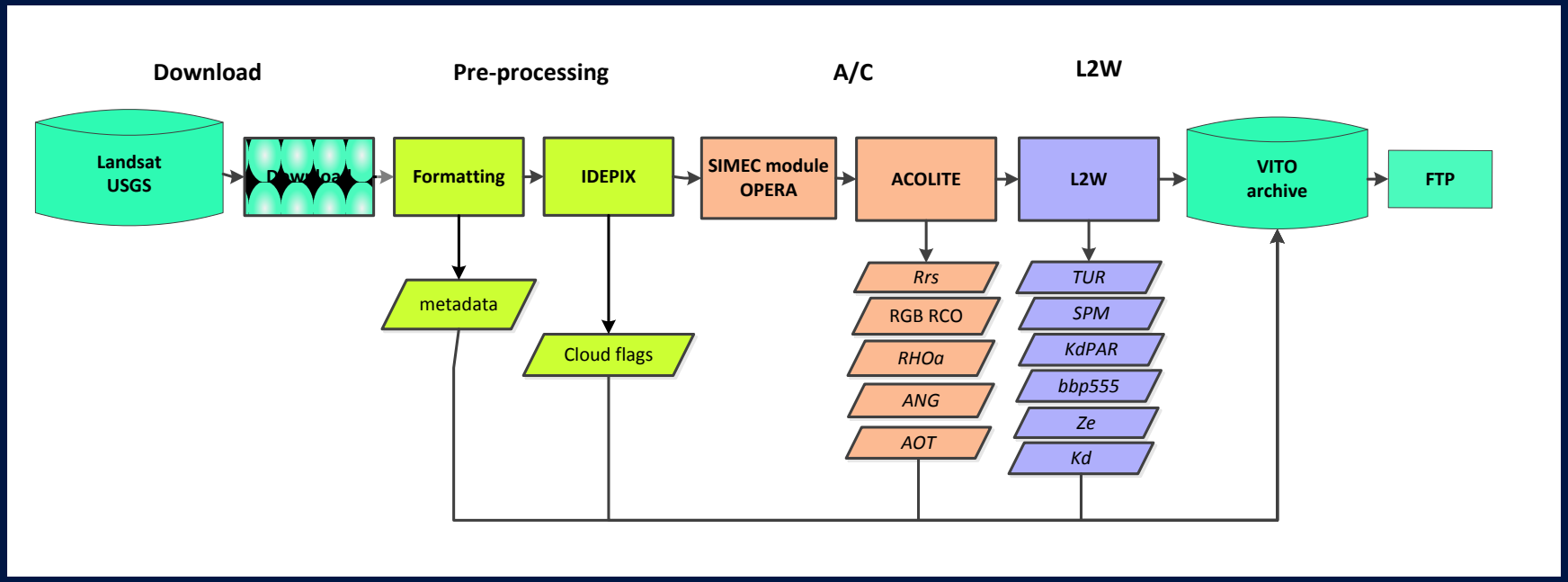


Highroc_sites

Site

- Belgian North Sea RBINS
- Belgian North Sea VITO
- French coastal Waters Gironde estuary (France)
- French coastal Waters Gironde upstream
- French coastal Waters Loire River plume and Bourgn
- French coastal Waters Rhone river plume (France)
- French coastal waters Gironde upstream
- German Coastal waters - Gustav Dalen
- German Coastal waters - Skattegat
- German coastal waters - Northern Stockholm archipelago
- German coastal waters - Elbe river estuary
- Norwegian waters: Inner Oslofjord region
- Norwegian waters:Bergen region
- Norwegian waters:Erfjord region
- Norwegian waters:Hvaler region
- Norwegian waters:Isfjorden and Van Mijenfjorden
- Norwegian waters:Outer Oslofjord region
- Norwegian waters:Trondheimsfjorden region
- Southern coastline Singapore
- UK Waters offshore windfarm sites 1
- UK Waters offshore windfarm sites 2
- UK Waters offshore windfarm sites 3
- UK Waters offshore windfarm sites 4
- UK Waters offshore windfarm sites 5
- UK waters: north east Irish Sea including Morecamb
- UK waters: south coast of England WFD regions

Highroc L8 work flow



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Highroc parameters L8

Parameter (units)	Symbol	Type
Remote sensing reflectance spectrum (sr^{-1}) at water level	Rrs	L2R
Aerosol reflectance spectrum	RHOa	L2R (aux)
Aerosol reflectance Angstrom exponent	ANG	L2R (aux)
Aerosol optical thickness	AOT	L2R (aux)
Suspended Particulate Matter (g m^{-3})	SPM	L2W/S
Turbidity (FNU)	TUR	L2W/S
Particulate backscatter at 555nm (m^{-1})	bbp555	L2W/S (aux)
Diffuse attenuation coefficient spectrum (m^{-1})	Kd	L2W/K
Diffuse attenuation coefficient of PAR (m^{-1})	KdPAR	L2W/K
Euphotic depth (m)	Ze	L2W/K
RGB Image (Rayleigh corrected)	RGB	L1

Highroc parameters S2

Parameter (units)	Symbol	Type
Remote sensing reflectance spectrum (sr^{-1}) at water level	Rrs	L2R
Aerosol reflectance spectrum	RHOa	L2R (aux)
Aerosol reflectance Angstrom exponent	ANG	L2R (aux)
Aerosol optical thickness	AOT	L2R (aux)
Suspended Particulate Matter (g m^{-3})	SPM	L2W/S
Turbidity (FNU)	TUR	L2W/S
Particulate backscatter at 555nm (m^{-1})	bbp555	L2W/S (aux)
Chlorophyll a (mg m^{-3})	CHL	L2W/C
Algal pigment absorption coefficient at 443nm (m^{-1})	apig443	L2W/C (aux)
Diffuse attenuation coefficient spectrum (m^{-1})	Kd	L2W/K
Diffuse attenuation coefficient of PAR (m^{-1})	KdPAR	L2W/K
Euphotic depth (m)	Ze	L2W/K
CDOM absorption coefficient at 443nm (m^{-1})	aCDOM443	L2W
Secchi Depth (m)	SD	L2W
RGB Image (Rayleigh corrected)	RGB	L1

Proba4Coast and PV-LAC

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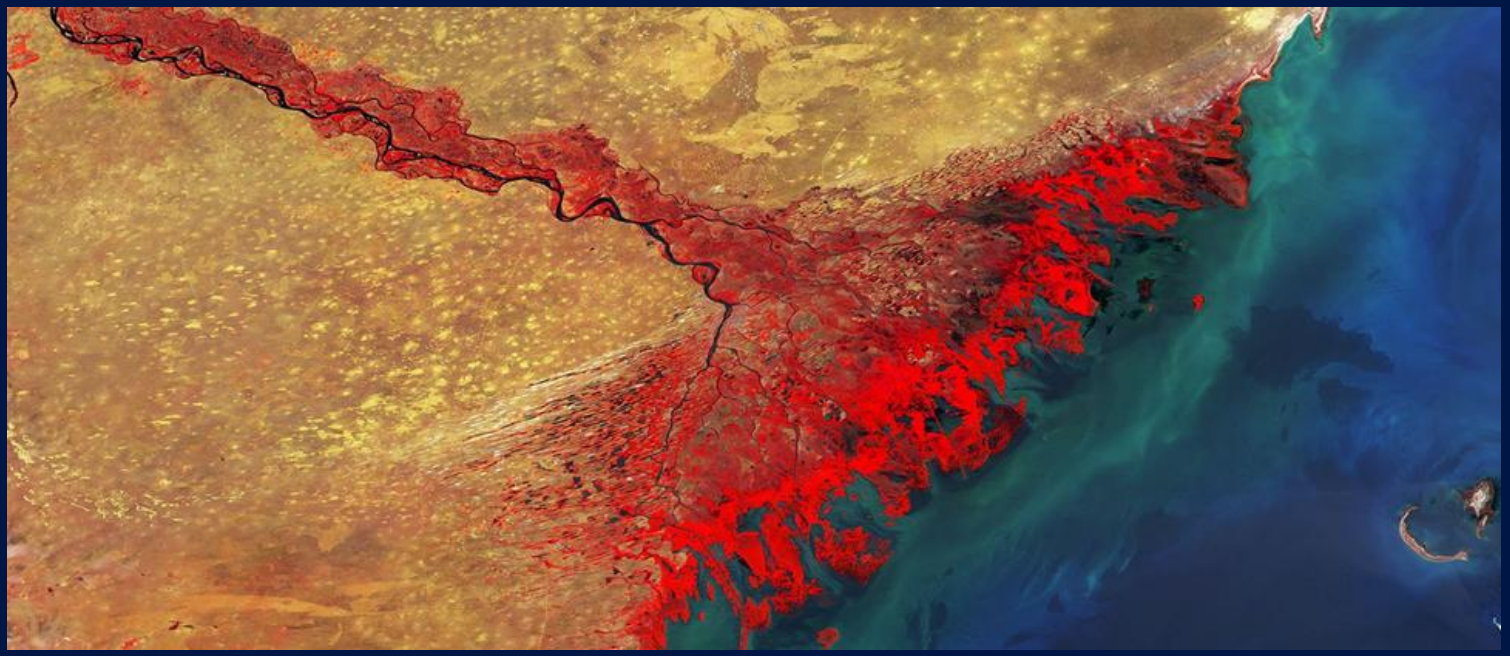
ProbaV for total suspended matter mapping in coastal areas

http://proba-v.vgt.vito.be/



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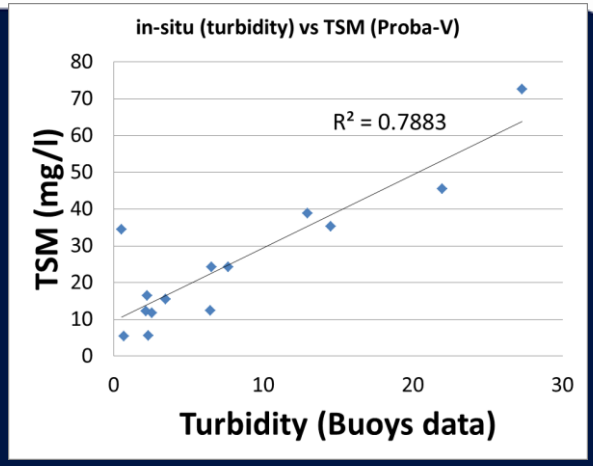
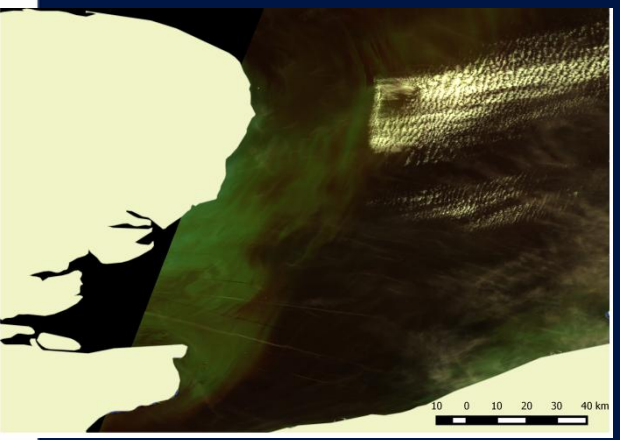
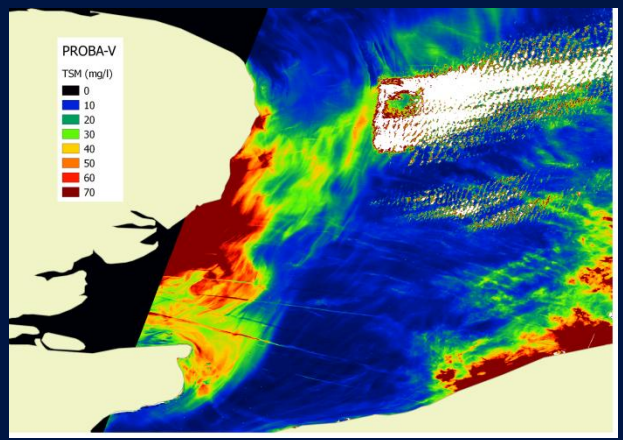
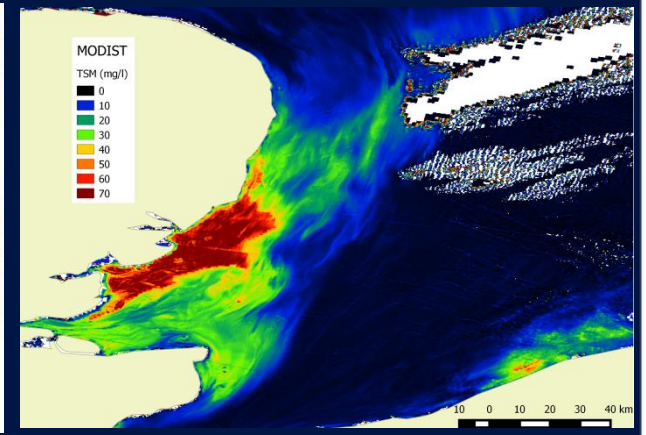
First results



Direct Validation through comparison with in-sit
Turbidy data from Buoys







Indirect validation (Left) PROBA-V true color image (acquisition date/time 21 April 2015 /11:06) ; (middle) PROBA-V TSM product ; (right) MODIS-Terra TSM map (acquisition date/time 21 April 2015 /10:50) Nechad et al. (2010) and wavelength switching

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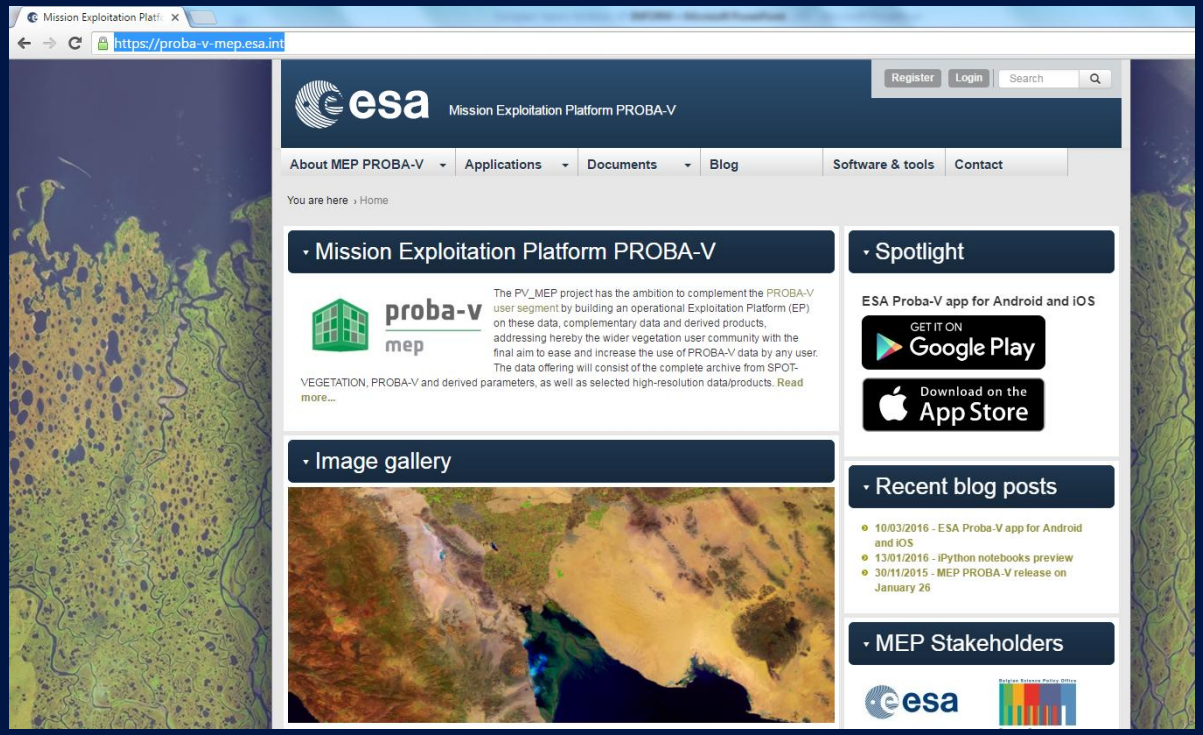
ESA MEP PROBA-V

https://proba-v-mep.esa.int/



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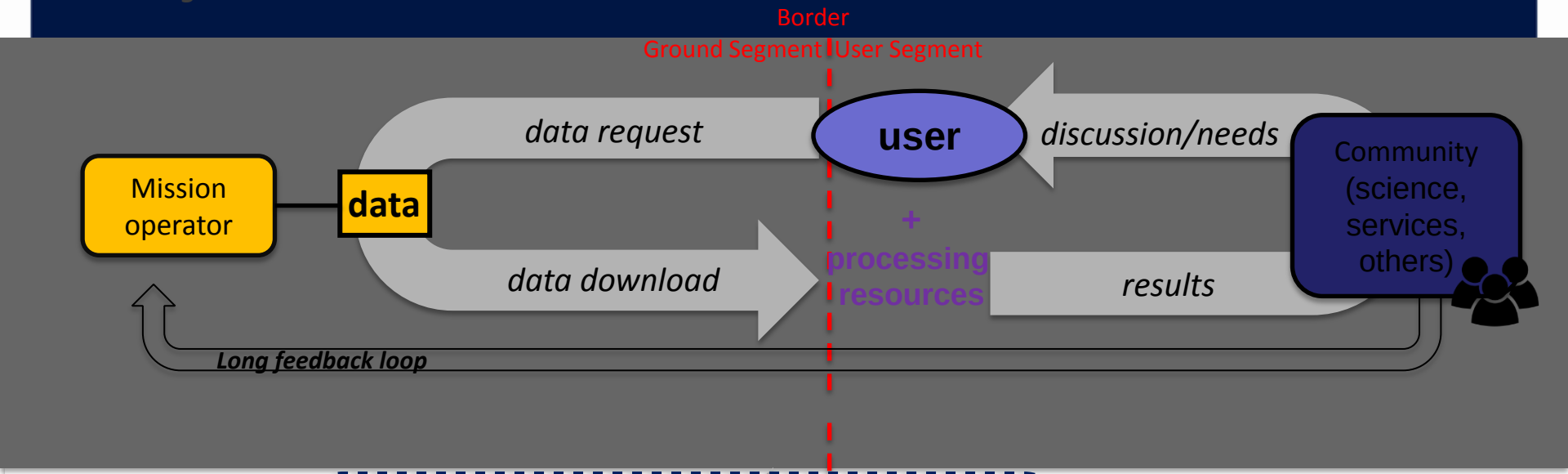
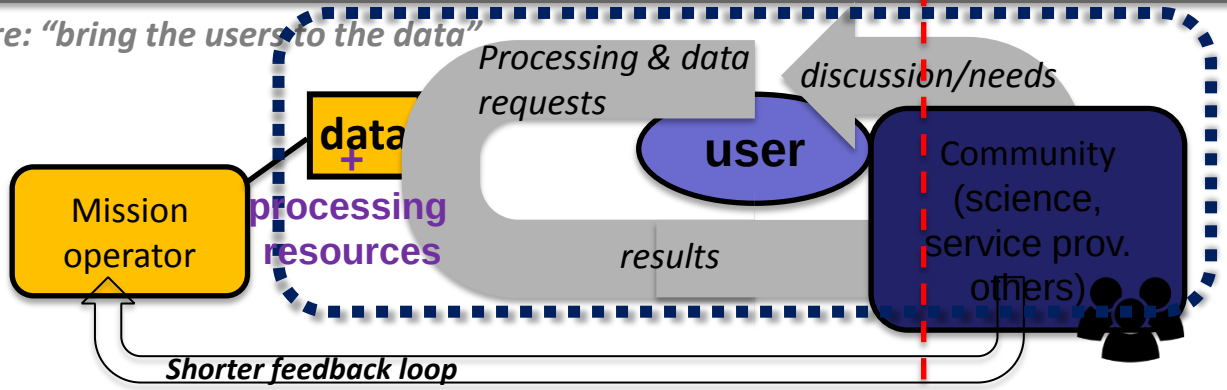
"bring the users to the data"

Current: "bring the data to users"



Future: "bring the users to the data"



Easier for user
More data
More results
Better service
More community spirit

User segment is within the Ground segment

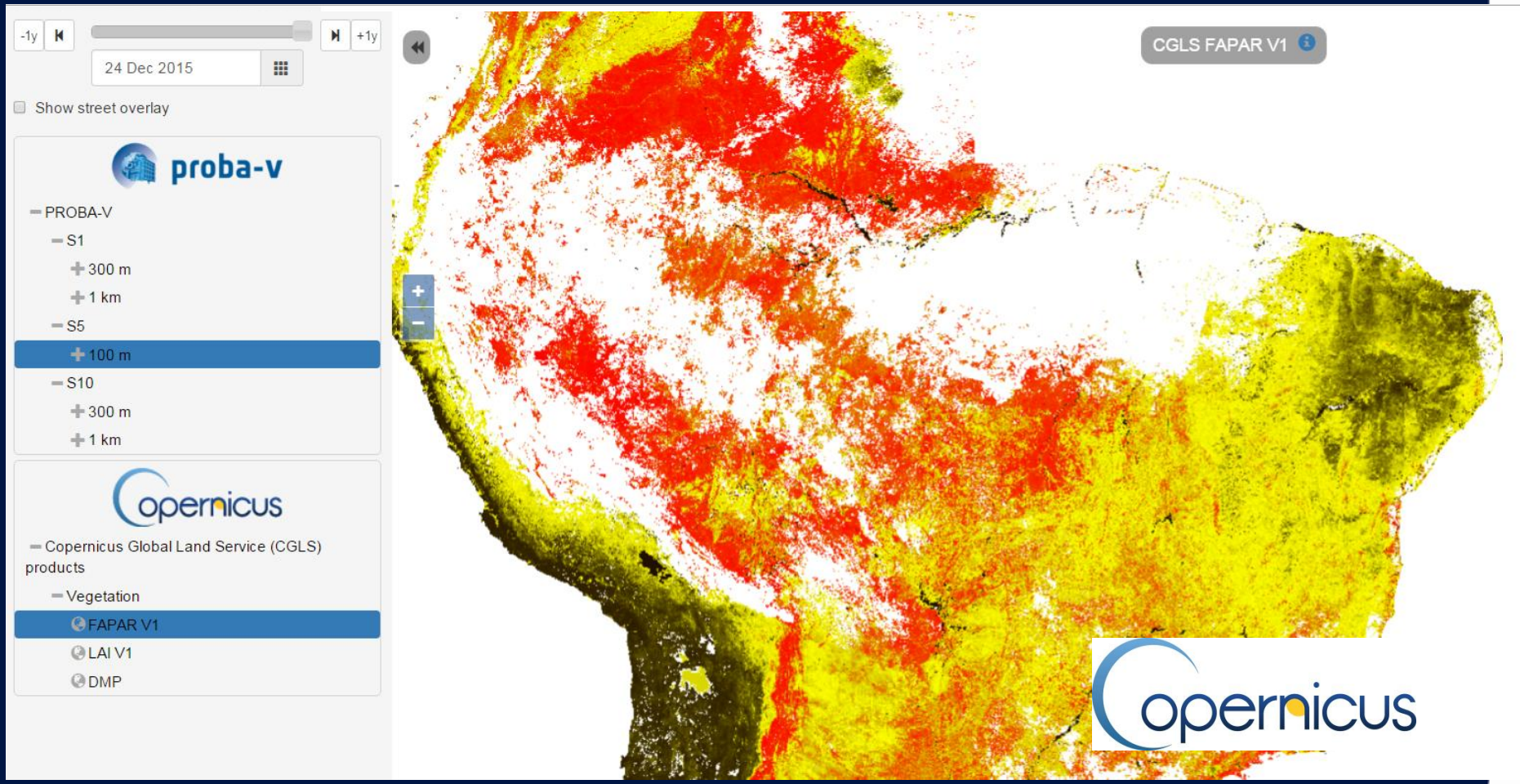
PROBA-V MEP APPLICATIONS

Support diverse user community

- Time Series Viewer – *Interactive visualization of long timeseries*
- On demand timeseries – *Analyze your own ROI*
- GeoViewer – *Full resolution viewing of satellite imagery*
- N-daily Compositor – *Create composites on-demand*
- Ipython notebooks – *Write your own experiments on full dataset in the browser*
- Toolbox Virtual Machine – *Flexible R&D environment with direct data access*
- More to come!

All backed by distributed processing environment (Hadoop) to provide flexible and scalable processing solution.

GEO VIEWER ROADMAP



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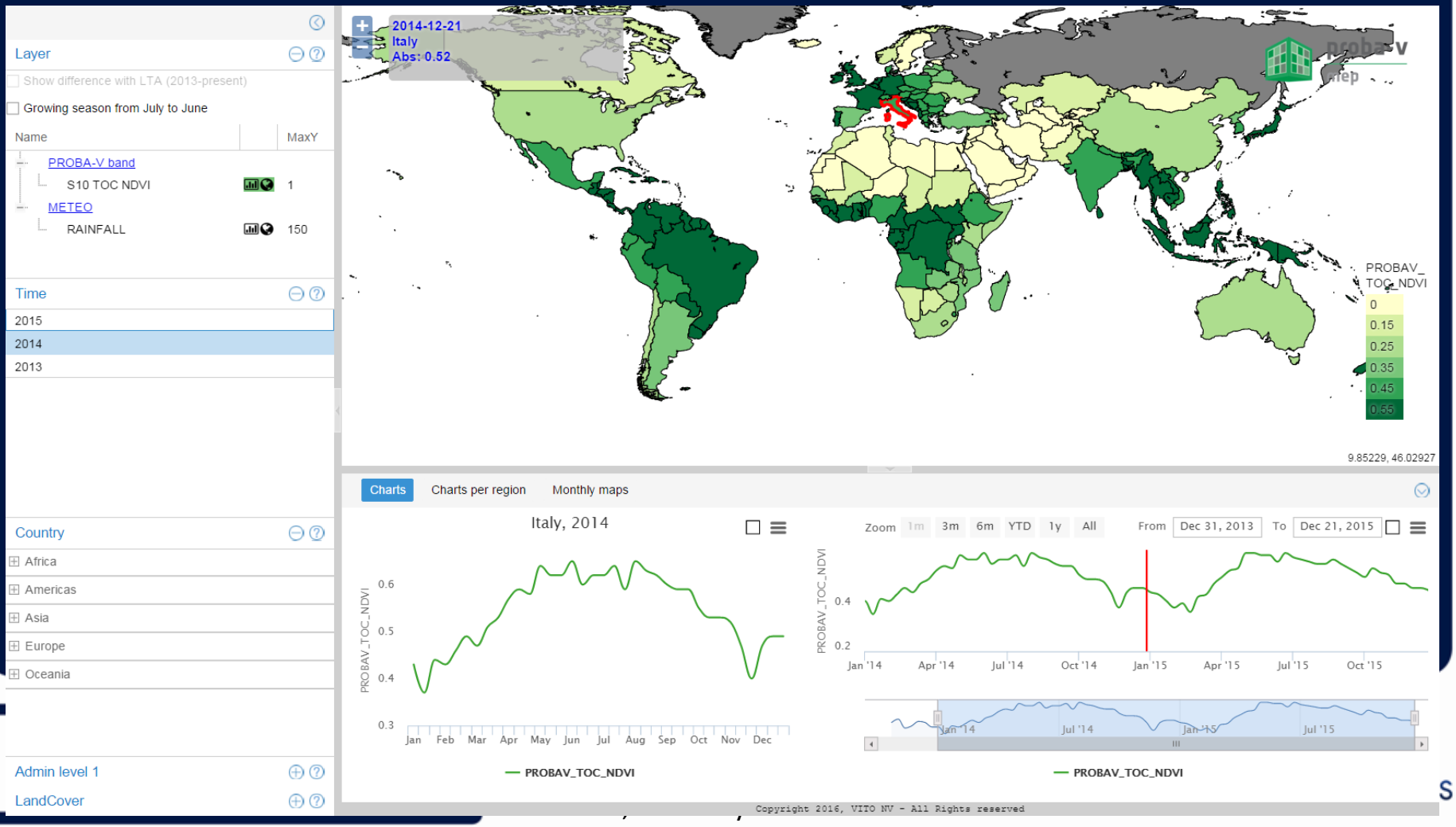
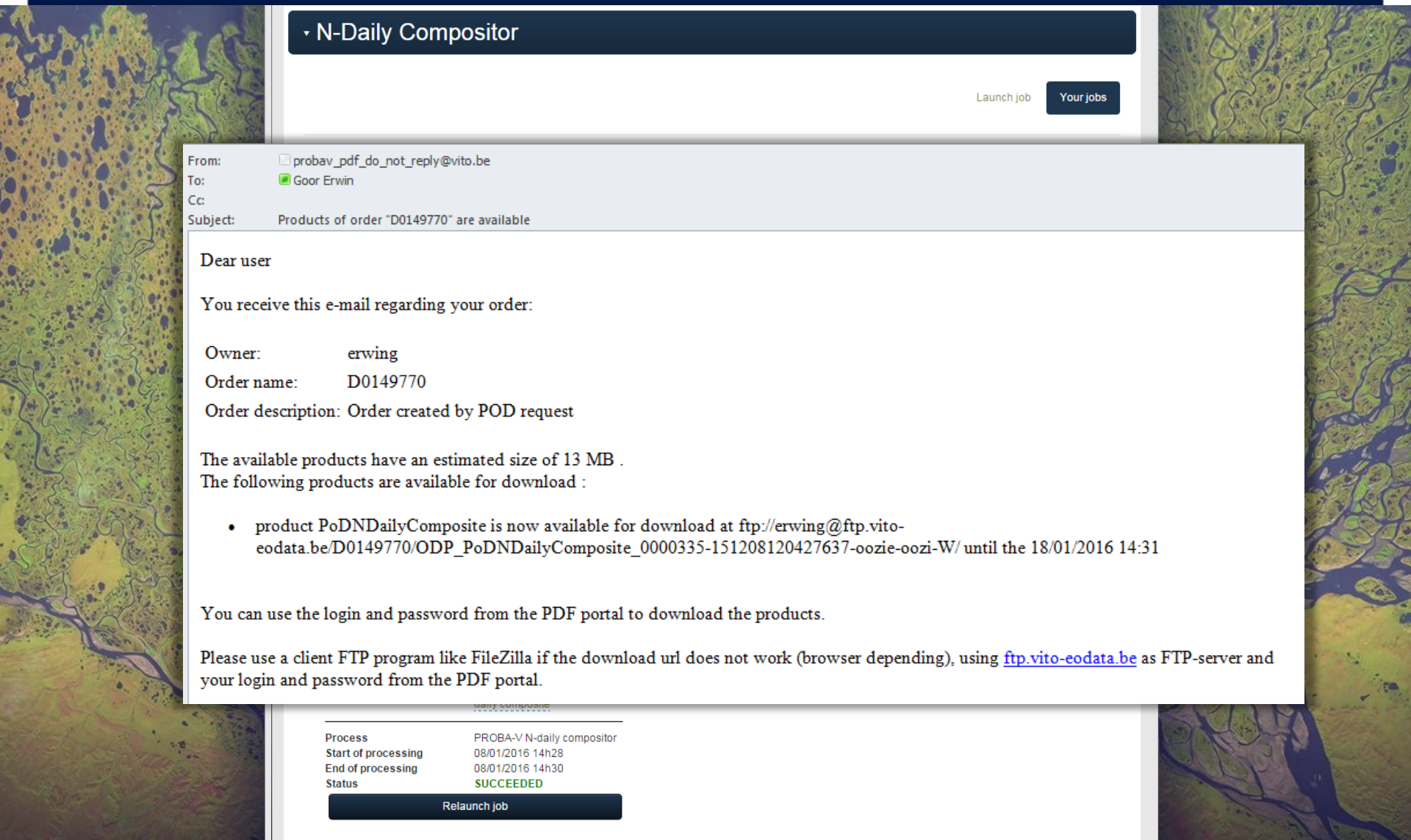
TIME SERIES VIEWER

Quickly explore & review satellite time series and complementary indicators for environmental monitoring



N-DAILY COMPOSITOR

First example of pre-defined on-demand processing service



IPYTHON NOTEBOOK

Interactive Data Analysis
&
Rich Media Output

WEB-BASED INTERACTIVE COMPUTING

A notebook records & distributes 'reproducible' research

Roadmap

- Available for demonstrations (on-demand)
- Released in 2017 to all users

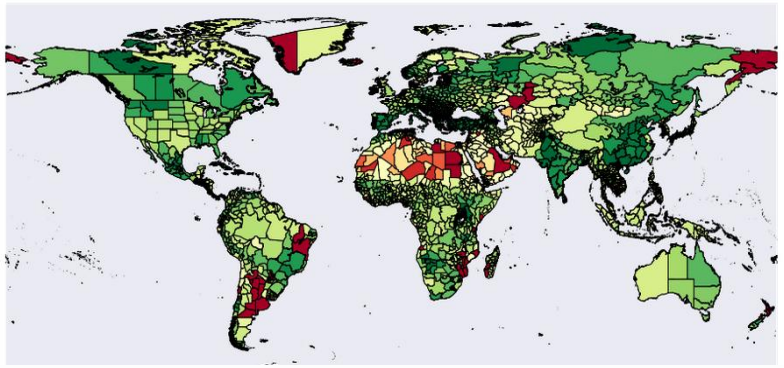
```
midpoint = 1 - vmax/(vmax + abs(vmin))
colormap = shiftedColorMap(plt.get_cmap('RdYlGn'), midpoint=midpoint, name='shifted')

pc = PatchCollection(patches, cmap=colormap, linewidths=1., zorder=2)
pc.set_array(np.array(colors))
pc.set_clim([vmin, vmax])
ax.add_collection(pc)
plt.colorbar(pc)

plt.show()
```

This is what it looks like worldwide.

In [20]:
```
plot_map(trend_by_zone)
```



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HELP THE EC SHAPE THE FUTURE OF COPERNICUS!

User Requirements Gathering for the Next Generation Copernicus Space Segment cross-sectoral online survey:

http://www.copernicus.eu/nextspae-cross-user-needs-survey

INFORM

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Copernicus