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PV-LAC: Advanced Land, Aerosol and Coastal Products for PROBA-V

PV-LAC: D-12-A3: Scientific Roadmap – Activity 3

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V2.1	2017/10/27	Chapter 2	Some clarifications added	Sindy Sterckx

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A/C	Atmospheric correction
ACIX	Atmospheric Inter-Comparison Exercise
BELSPO	Belgian Science Policy Office
CEFAS	Centre for Fisheries and Aquaculture Science
CEOS	Committee on Earth Observation Satellites
COST	European Cooperation in Science and Technology
ENVI	Environment for Visualising Images
GeoTIFF	Georeferenced Tagged Image File Format
HDF	Hierarchical Data Format
IDL	Interactive Data Language
IVOS	Infrared and Visible Optical Sensors Subgroup
LUT	Look-Up Tables
MEP	Mission Exploitation Platform
MM	Man-Month
NetCDF	Network Common Data Format
RSR	Relative Sensor Response curve
S3VT	Sentinel-3 Validation Team
SIMEC	Similarity Environment Correction
SNAP	SentiNel Application Platform
STA	Stand Alone Adapter
TEP	Thematic Exploitation Platforms
WGCV	Working Group on Calibration and Validation

CHAPTER 1 INTRODUCTION

1.1. PURPOSE OF THE DOCUMENT

The Roadmap document discusses a number of elements that relate to the future of the coastal products based on the PROBA-V 100 m data.

CHAPTER 2 IMPLEMENTATION

2.1. INTRODUCTION

In the frame of the PV-LAC project a prototype code has been developed, tested and validated for the atmospheric correction (A/C) and turbidity retrieval of PROBA-V data over turbid coastal areas. The A/C prototype code is based on the iCOR (previously known as OPERA) code, originally developed for Landsat-8 and Sentinel-2. The turbidity retrieval code is based on the approach developed by Nechad et al. (2009), later improved by Dogliotti et al. (2011).

The validation results obtained within PV-LAC clearly illustrate the high potential of PROBA-V for coastal product generation. However, in order to fully and/or globally explore the potential of PROBA-V for the generation of coastal products, the code should be implemented in more operational environment which should be accessible to external users.

Considering the strong evolution and visibility of **Thematic Exploitation Platforms** (TEP), initiated by ESA, a coastal PROBA-V application tool (including both A/C and turbidity) could be implemented and run in such environment. We are considering here the following two exploitation platforms:

1) the PROBA-V Mission Exploitation Platform (MEP) (https://proba-v-mep.esa.int/)
2) the Sentinel Application Platform SNAP (http://step.esa.int/main/toolboxes/snap/)

Implementation within the **PROBA-V MEP** platform has the following advantages:

1) the user has direct access to all PROBA-V images and can thus process large time series of PROBA-V over a coastal area of interest, without the need to download the input data (no data transfer needed).
2) the MEP contains already various tools (including SNAP) for time series analyses and visualisation, which can easily be adapted to coastal applications.

Implementation within the **SNAP platform** has following advantages:

1) within SNAP, the iCOR A/C tool will already be released for both Landsat-8 and Sentinel-2. This allows users to process PROBA-V, Landsat-8, and Sentinel-2 over their area of interest with the same A/C code and therefore minimizing the risk of biases in atmospherically corrected products due the use of different A/C method.
2) as SNAP is the application platform for all Sentinel missions, a more diverse and larger user community might be attracted.
3) Although SNAP has designed in the first phase for the exploitation of Sentinel data, a PROBA-V toolbox is already made available allowing to read PROBA-V data within SNAP. The multi-mission philosophy of SNAP facilitates users in processing and combining data from various missions.

The major drawback of an implementation within SNAP is that users still need to download PROBA-V data (unless they run SNAP on the MEP), making it mainly suitable for small-scale studies. Therefore for large-scale processing the MEP environment is the preferred option.

2.2. Effort needed

Below follows a brief description of the work to be performed before implementation in the MEP and/or SNAP.

2.2.1. Implementation of iCOR in the MEP

The following steps are needed to implement PROBA-V coastal product generation within MEP:

- Develop workflow for conversion of PROBA-V files into an iCOR compatible data format Conversions are needed for the radiance grids , viewing and solar angular grids, and status map.
- Develop workflow for download and conversion of (ECMWF) meteo data
- Develop worklow for generation of iCOR configuration files
- Develop workflow for automatic processing of PROBA-V 100 m over user selected test site within user defined time period.
- Testing/debugging

The following Table summarizes the main tasks and a first estimate of the associated effort express in man-month (MM). Some additional validation excercises are currently being performed in order to evaluate the use of iCOR for the operational processing of PROBA-V. The efforts listed in the table below do not include the additional efforts which will be needed to implement iCOR in the user segment (like for instance fall-back strategies, parallel processing etc).

Table 1: Effort estimate for coastal product generation in MEP.

Task	Estimated effort in MM
Workflow for conversion of PROBA-V data into iCOR compatible	0.5
Workflow meteo data	1
Workflow iCOR config generation	1
Workflow processing PROBA-V over ‘user’ defined area (command line)	1
Basic User interface (optionally)	1.5
Testing and debugging	1
Total	**4.5 (+1.5 optionally)**

2.2.2. Implementation of iCOR for PROBA-V within SNAP

The following steps are needed to develop an ICOR version for PROBA-V within SNAP:

- **PROBA-V readers**
  The PROBA-V data are distributed in HDF5 format. Currently, some preliminary prototype scripts have been written in Interactive Data Language (IDL) to generate the necessary data (i.e., radiance grids , viewing and solar angular grids) in a format compatible with iCOR.

These prototype scripts need to be rewritten in a language supported by SNAP and further optimized in order to perform the conversion job more efficiently.

- **Development of iCOR-SNAP Stand Alone Adapter (STA) for PROBA-V**, comparable to the iCOR SNAP STA already available for Sentinel-2 and Landsat-8 (see https://blog.vito.be/remotesensing/icor_available).
- **Software verification of the STA:** testing of the iCOR STA on a series of scenes to verify the correctness of the implementation and to find possible bugs in the implementation.

The following Table summarizes the main tasks and a first estimate of the associated effort express in man-month (MM).

Table 2: Effort estimate iCOR for PROBA-V in SNAP.

Task	Estimated effort in MM
PROBA-V readers for ICOR/SNAP	1
Implementation iCOR for PROBA-V in SNAP	3
Software verification and debugging	1
Total	**5**

CHAPTER 3 MULTI-MISSION APPLICATION

3.1. INTRODUCTION

The Requirement Baseline Document clearly showed that there is a high interest in an almost daily coverage at a resolution of 100 m or better. As this high temporal coverage combined with a high spatial resolution cannot be provided by a single sensor such as PROBA-V, data from different (mainly non-ocean colour missions) need to be combined. In this frame, PROBA-V 100 m coastal products could be combined with Sentinel-2 and Landsat-8 products. However, also data from commercial sensors such as Deimos-DMC or WorldView could be considered in order to increase the temporal resolution. Finally, for offshore areas where a lower spatial resolution is sufficient, data from ocean colour missions such as Sentinel-3 could be added.

This **joint data usage from different sensors** raises some clear concerns about **data consistency**, especially when a seamless data combination is needed witin an operational service. Differences in the final products could arise from calibration differences in the L1 data, biases introduced through the use of different algorithms or processors, spectral response differences, etc.

The missions are calibrated by a different team of Cal/Val experts which use their own methods. Therefore although these sensors are all calibrated within their absolute radiometric accuracy requirements, cross-sensor radiometric biases might exist. Furthermore, it should be noted that the considered missions have been primarily designed for land surface applications, therefore there might have been no requirements for the instrument team on the verification of the radiometry at low radiances (which is for instance the case for PROBA-V). Therefore it is expected that larger biases might exist between the sensors for low radiance and that different gains might be applicable. Furthermore, due to **instrument response non-linearity effects,** the nominal calibration coefficients might not be applicable for low sensor signals observed over water targets.

In order to harmonize the L1 data provided by the different agencies and/or data providers, there is clearly a need for joint inter-calibration inititiatives, which are not limited to consistency analyses over bright land targets only. A joint intercalibration initiative could be inititiated through the Committee on Earth Observation Satellites Infrared and Visible Optical Sensors Subgroup (CEOS IVOS), and/or by the various space agencies. A dedicated roadmap for the **harmoninisation of L1** data, although very important, is considered out-of scope of the PV-LAC project.

Biases in L2 data (and final turbidity) can also be introduced due to differences in applied A/C codes. A way forward would be the use of a **common A/C tool** for all missions. Within this respect iCOR might be of interest. iCOR is made available through the SNAP platform for both Sentinel-2 and Landsat-8 processings and has been thoroughly validated and inter-compared in the frame of the CEOS Working Group on Calibration and Validation (WGCV) Atmospheric Inter-comparison Exercise (ACIX). Furthermore, within PV-LAC it has been validated for PROBA-V data as well. Through the integration of the Similarity Environment Correction (SIMEC) adjacency correction approach (i.e., for L8 and S2) there is also a high interest from the inland water community. **Currently, an iCOR version for OLCI (Sentinel-3) is still lacking.**

3.2. EFFORT NEEDED

3.2.1. ICOR VERSION FOR OLCI SENTINEL-3

The following steps are needed to develop an iCOR version for OLCI

- Generation of OLCI specific LUTs: based on the available Relative Sensor Response curve (RSR's) a S3 specific Radiative Transfer Look-Up-Table (LUT) will be created. The creation of this lookup table requires the assessment of mission specific lookup table boundaries for among others the view zenith angle, solar zenith angle, and relative azimuth angle. The calculation of the LUT is parallelised and fully automated and performed on a multiprocessor platform.
- OLCI L1 readers for iCOR: OLCI Sentinel-3 (S3) data is distributed in a proprietary file format. The Network Common Data Format (NetCDF) format used is currently not directly addressed in the iCOR atmospheric correction C++ toolbox. Conversion is required for the following grids :
    - radiance grids (actual pixel values)
    - tie geometries (view and solar angles)
    - geo_coordinates (dem and/or lat lons)
- Adaptation of iCOR to the OLCI spectral, geometric, and radiometric characteristics.
- Validation of the intermediate AOT products with AERONET data.
- Validation of water leaving reflectance on the basis of Aeronet-OC data or in-situ data (acquired for example in the frame of S3VT).
- Impact of the OLCI vicarious adjustment coeffients for marine A/C

Optionally:

- Inter-comparison with OLCI standard marine A/C.
- Implementation in SNAP: The iCOR software can run completely stand-alone. However, for user interaction and convenience integration into SNAP as a Stand Alone Adapter (STA) is desirable. There will be an adapter specific to S3, but it is based on the experience with Landsat-8 and Sentinel-2. The complexity will rely heavily on the treatment of the data through the wrapper code.

The following Table summarizes the main tasks and a first estimate of the associated effort express in man-month (MM).

Table 3: Effort estimate iCOR for Sentinel-3 in SNAP

Task	Estimated effort in MM
Adjustments to iCOR for OLCI-S3	4
Validate the iCOR version for S3 with field data	3.5
ICOR-S3 for SNAP	2
Total	**9.5**

3.2.2. EVALUATION OF POSSIBLE NON-LINEARITY OF PROBA-V

The following steps could be done to verify the linearity of the PROBA-V response over low radiance targets.

- Specific non-linearity acquisition over large, homogenous water targets. In the non-linearity acquisition the integration time of the PROBA-V instrument is in-/decreased in steps allowing to verify if the response is linear with respect to integration time/input radiance.

- Vicarious calibration validation over AERONET Ocean Colour (OC) sites (*).

The following Table summarizes the main tasks and a first estimate of the associated effort express in man-month (MM).

Table 4: Effort estimate verification PROBA-V response linearity over low radiance targets.

Task	Estimated effort in MM
Non-linearity acquisitions (planning, analyses)	1
Vicarious calibration validation over Aeronet-OC sites *	3
Total	**4**

* Within the Stereo III programm VITO submitted a proposal, called Belharmony, which aims to assess and to improve the consistency of multi-sensor high resolution time series generated on the basis of the following sensors: Deimos-1, Sentinel-2, Landsat-8, and PROBA-V. The project has recently been approved and will start in 2018. One of the tasks within Belharmony will be the verification of the PROBA-V radiometry at low radiance levels using AERONET OC observations.

CHAPTER 4 VALIDATION

4.1. INTRODUCTION

Within PV-LAC, the AERONET(-OC) Network has proven to be very useful for validation of the water-leaving radiance reflectance for the the intermediate AOT product validation. Similarly, the Centre for Environment, Fisheries and Aquaculture Science (CEFAS) smartbuoys provided a wealth of data for the calibration of the PROBA-V turbidity results in the Southern North Sea. In order to better verify the global applicability of the turbidity algorithm, turbidity data from more coastal sites would be needed. To our knowledge, however, no network and/or database of **globally distributed turbidity measurements** exists. Recently, Dogliotti et al. (2016) proposed TURBINET, a long-term (autonomous) international network of collaboration and data-sharing for the validation of satellite derived turbidity products. We believe that such a network is critical for quality control of satellite imagery.

Besides the need for a global network/database of turbidity instruments, more scientific research is required to understand possible **differences in turbidity values** given by various turbidity meters. For instance the Smartbuoys are equipped with a Seapoint turbidity meter with operating wavelength at 880 nm and recording light scattered by suspended particles between 15° and 150°. The Nechad (2009) algorithm is developed based on measurements with a HACH portable turbidity meter with operating wavelength at 860 nm and recording side scattering at 90°. Despite the fact that they are both calibrated with standard Formazine suspensions, their response in natural waters might differ (Roesler and Boss, 2008), because of the intrinsic difference in measurement method.

4.2. EFFORT NEEDED

4.2.1. TURBIDITIMETER INTERCOMPARISON

Intercomparison of various turbidity meters (including at least Smartbuoys Seapoint and a HACH portable turbidity meter) for a diverse range of conditions.

A limited intercomparison activity has been performed in the frame of the BELSPO funded PROBA-4Coast project. However a more extensive comparison in various types of waters would be required. This type of activity could for instance be part of a large European/International project and/or within a COST action.

A detailed effort estimate is considered out of the scope of the current PV-LAC project.

CHAPTER 5 OTHER COASTAL PRODUCTS

5.1. INTRODUCTION

PV-LAC has shown the potential of PROBA-V for mapping of turbidity (and total suspended matter) in coastal water areas. However, turbidity is not the only coastal/water product for which PROBA-V data could be interesting.

For example, it might be worthwhile to investigate if the diffuse attenuation coefficient, Kd(λ), which is an important optical property and linked to light penetration and availability in aquatic systems, could be derived from PROBA-V observations.

PROBA-V 100 m data might also be suited for coastal erosion monitoring and/or coastline change using spectral unmixing algorithms (Keshava and Mustard, 2002) for deriving the sub-pixel water fraction within a 100 m pixel, which is then used for calculating the sub-pixel coastline coordinate.

5.2. EFFORT NEEDED

The following Table summarizes the main tasks and a first estimate of the effort needed to develop a PROBA-V Kd product

Table 5: Effort estimate to develop a PROBA-V diffuse attenuation coefficient product.

Task	Estimated effort in MM
Literature review/Selection appropriate algorithms	0.5
Implementation	0.75
Testing and Validation	1.5
Total	**2.75**

CHAPTER 6 SEDIMENT TRANSPORT MODELS

6.1. INTRODUCTION

In order to improve the understanding of the coastal dynamics at a fine spatial and temporal scale, EO-derived Turbidity maps should be linked with sediment transport models. On one hand, sediment transport models could be used to explain for example turbidity variations between image acquisitions by different satellites at different times during the day. On the other hand, EO-derived Turbidity maps could be used for validation and calibration of the sediment transport models.

Furthermore, sediment transport models can allow to explain the importance of potential 3D effects (e.g. vertical stratification) and the importance of flocculation and how they may affect the EO-derived turbidity images.

6.2. EFFORT NEEDED

A related activity is currently being performed within the BELSPO funded PROBA4Coast project, in which a comparison is ongoing between the turbidity derived from remote sensing data and a model developed for the North Sea area. The model for the North Sea area has been set up using the TELEMAC-MASCARET model suite consisting of a hydrodynamic module (TELEMAC), a wave module (TOMAWAC) and a sediment transport module (http://www.opentelemac.org/). The sediment transport module can estimate sediment concentrations, which can be compared to the SPM/turbidity values estimated from RS images. The model can be run in 2D or 3D. The 3D approach makes it possible to assess the vertical concentration variation.

A detailed effort estimate is considered out of the scope of the current PV-LAC project.