Cloud Detection Round Robin for Proba-V

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Motivations

- **Undetected clouds** still represent a major source of **uncertainty** for land (and atmosphere) applications, this was clearly highlighted during last **Proba-V Symposium**
- The operational Proba-V algorithm for cloud detection (**thresholds-based**), despite the clear **improvements**, part of the upcoming **reprocessing**, has **still some drawbacks** (e.g. over-detection in case of large sun/viewing angles)
- **Alternative methods** (Bayesian, statistical, NN) allow optimal use of all information from the spectrum and may be the solution to overcome the **intrinsic limitations of Proba-V** for clouds (only 4 bands and no TIR)
- It will provide useful **recommendations** for next Proba-V processor baseline, the acquired knowledge and lessons will be reused for **other optical missions** (S-3, S-2)

Cloud definition

- "A visible aggregate of minute water droplets and/or ice crystals suspended in the atmosphere"
- What is "**visible"**? It depends mainly on:
  - Sensor type (active/passive)
  - Spectral coverage (spectral bands: VIS, TIR)
  - Geometry of observation (viewing angles)
  - Cloud type (tick, thin, high, low), Surface type (dark, bright, cold) and the combination cloud/surface types (radiance contrast)
- Global total cloud coverage is about **70%** for COD>0.1 [GEWEX Global Cloud Assessment, 2013]
- Clouds are **hiding/perturbing the signal of interest** in many remote sensing applications (land, ocean, atmosphere)

Cloud Detection

- **Clouds** are generally (but <u>not always</u>): **brighter** (reflectance), **whiter** (reflectance slope), **colder** (BT), and have different **spatial/temporal** variability, w.r.t. the underlying **surface**
- These features can be used for cloud detection:
  - **Thresholds**: rely on contrast between clouds and clouds-free pixel and are based on single or multiple tests
  - **Statistical**: exploit various physical features combined in a statistically sound approach (e.g., machine learning, Bayesian)
  - **Spatial coherence**: use pattern recognition and a priori knowledge of cloud texture
  - **Multi-temporal**: use the fact that surface properties are much stable in time than clouds, i.e. clouds result in abrupt changes

Cloud Masking

- Is the process that results in a **per-pixel** quantification of the presence of cloud: either **binary** (yes/no), **multi/class** (yes/no/dubious), **continuous** (probability of cloud presence)
- Cloud mask can be:
  - **Clear-sky conservative**: i.e., over-estimate rather than underestimated the amount of clouds, best suited for land, ocean, snow/ice, atmosphere remote sensing
  - **Cloud conservative**: under-estimate the cloud presence, mostly suited for cloud properties retrieval
  - **Climatological**: balanced detection to be bias-free, self consistent and optimized for generation of climate data record

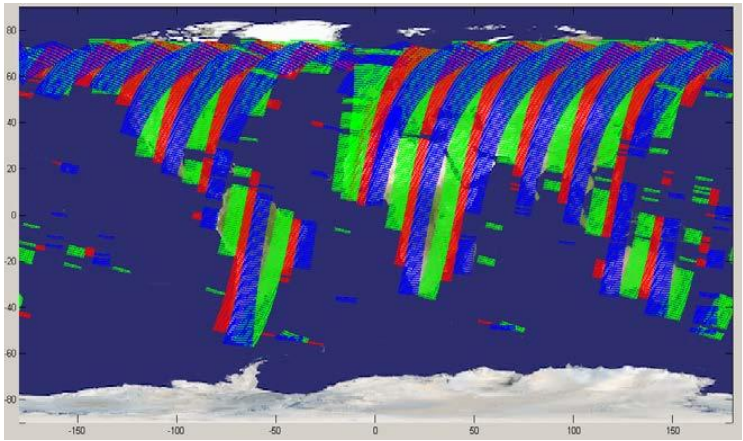
Cloud Mask Validation

- Validation is challenging because:
  - Cloud “visibility” depend on the instrument and viewing geometry
  - Clouds have strong spatial/temporal variability
  - Need to be representative of heterogeneous surface/clouds types
- Potential approaches include:
  - **Visual Inspection**: human eye recognition of clouds pattern is still considered the best approach for “validation”
  - **Ground-based**: either sparse active continuous instruments or synoptic meteorological observations, both have limitations in terms of coverage and spatial representativeness
  - **Satellite-based**: the most suitable approach for validation is to be on the A-train (or EarthCARE) and use collocated measurements from active sensors (CALIOP, ATLID), not applicable to different orbits

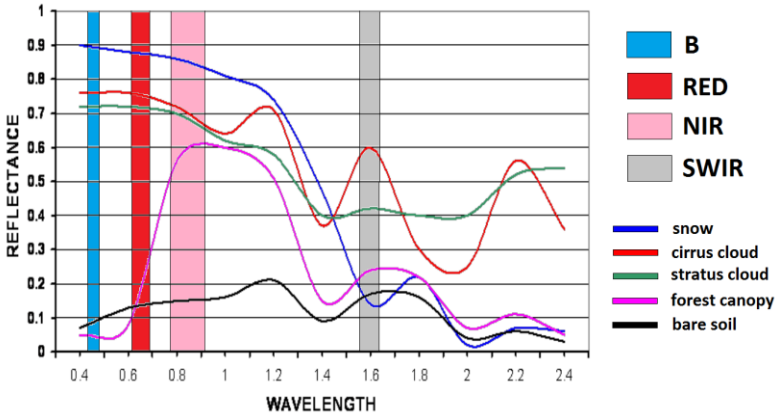
Proba-V and clouds

- Optical sensor in the **VNIR-SWIR** providing **global daylight** observation of **land masses**
- Main goal is **vegetation** monitoring at global scale bridging the gap of SPOT-4/5 VGT archive to S-3
- Products at 3 resolution: 1km, 333m, 100m (5 days revisit)
- Main **challenges** for clouds: limited bands, no TIR or dedicated band (e.g., cirrus band at 1.38µm)

Proba-V daily spatial coverage



Proba-V spectral coverage



Design of a Proba-V Round Robin on Clouds Detection

- To identify strengths/drawback of different algorithms
- Round Robin design:
  - Focus is on multi-class mask (cloud/clear/ambiguous)
  - Open to any interested algorithm providers
  - No ancillary data will be provided
  - No training dataset will be provided
  - Global input dataset (blinded) provided to participants
  - Validation data (hidden) based on manual (visually based) expert classification → best approach for algorithm inter-comparison
- Algorithm requirements
  - Automatic classification, no constraints on methodologies
  - Required output: cloud mask + ATBD

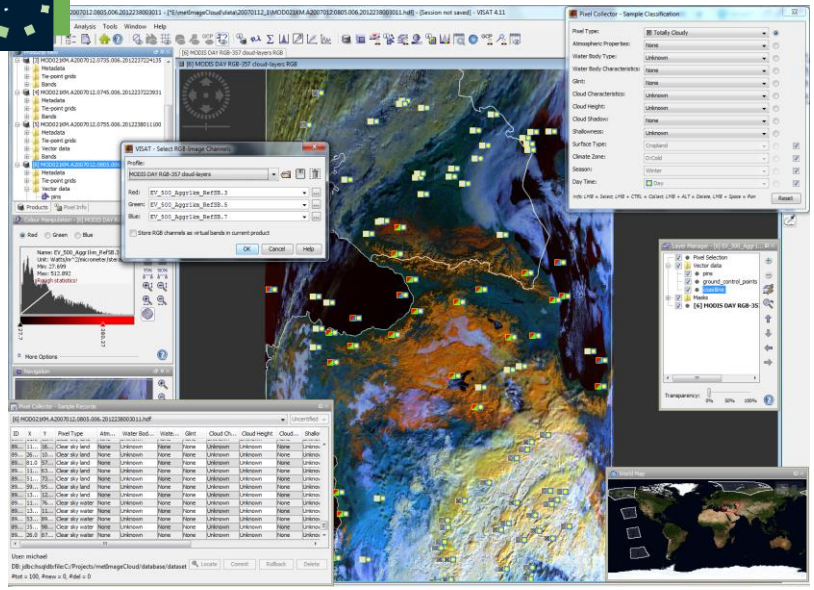
Data

- **Input data**: it is the data provided to all participants, needs to be global, representative of different seasons and blinded
  - 4 days (4 seasons) of Proba-V L2a TOA global data at 333m (no flags)
- **Validation Data**: it is the “truth” to be used for QA, it is hidden to the participants, needs to be global and representative of various conditions (different clouds, surface types, geometry of observation)
  - A large set of manually classified pixels (several 10K) from input data
- **Test Data**: it is a specimen of the validation data to be provided to the participants as indication of our pixel classification approach and nomenclature
  - A small but statistically representative subset of the validation data

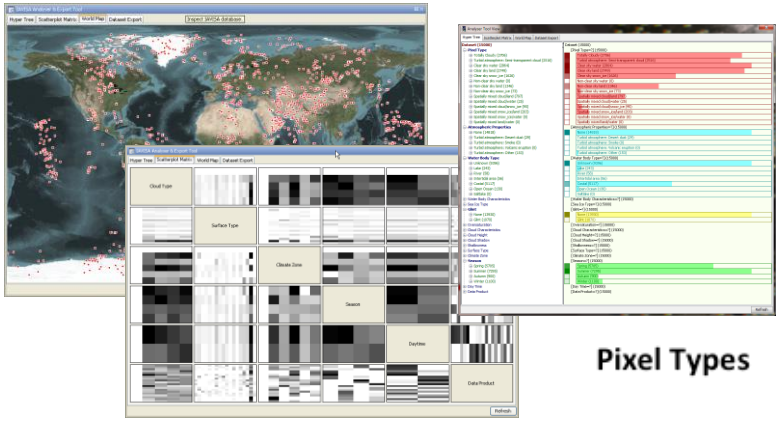
Validation data: PixBox

Developed by **Brockmann Consult** and used successfully in a number of ESA projects (LC, OC CCI) for the assessment of pixel classification algorithms

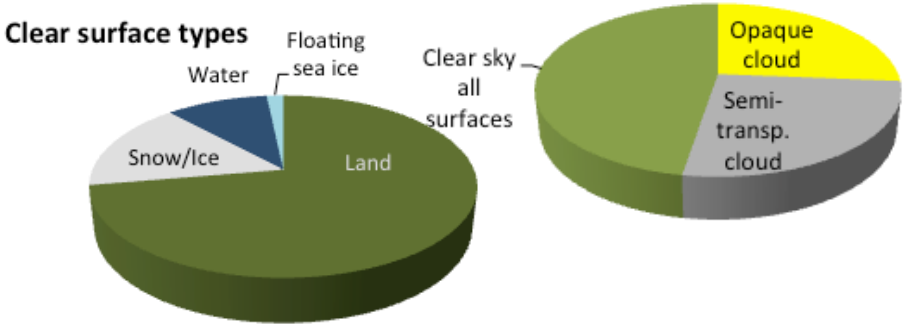
Pixel collection using BEAM/SNAP



Pixel DB analysis and QC

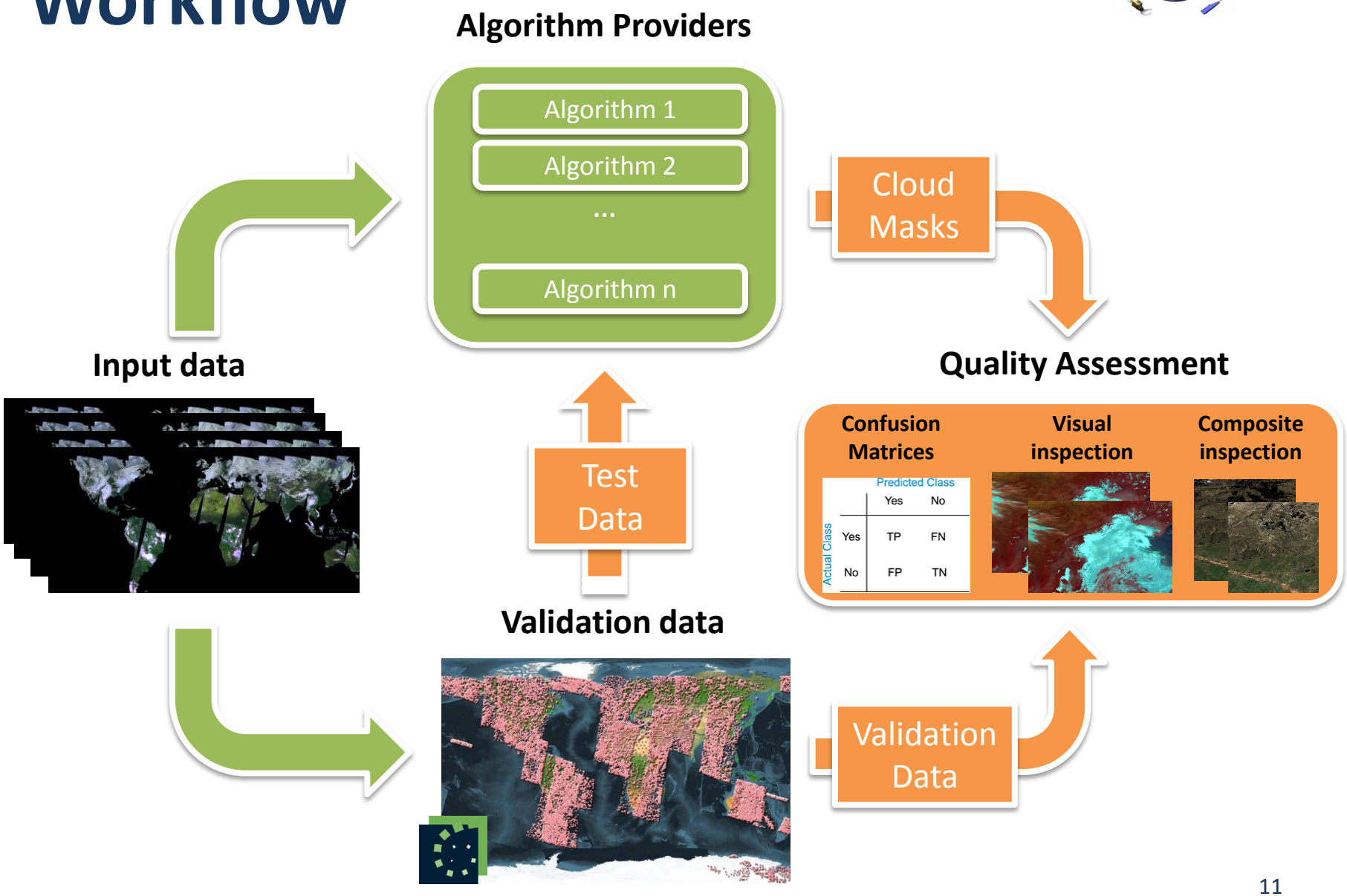


Pixel Types



Post-processing to verify geographical and statistical representativeness of database: e.g. Proba-V mission (70% land) covering global cloud coverage conditions.
Additional QC to identify human errors

Workflow


Algorithm Providers
Algorithm 1
Algorithm 2
...
Algorithm n
Cloud Masks
Input data
Quality Assessment
Confusion Matrices
Visual inspection
Composite inspection
Predicted Class
Yes
No
Actual Class
Yes
TP
FN
No
FP
TN
Test Data
Validation data
Validation Data

Quality Metrics 1: Confusion Matrices

- On the one side the Ground-truth class on the other side the Classifier class
- **Producer Accuracy (PA)**: or Accuracy is the fraction of correctly classified pixels with regard to all pixels of that ground truth class
- **User Accuracy (UA)**: or Reliability, is the fraction of correctly classified pixels with regard to all pixels classified as this class in the classified image
- E.g. clear-sky conservative: PA for clouds is very high, but we loose in UA, i.e., we flag all cloudy pixels, but also many clear pixels
- Several statistical indicators and metrics will be used in addition (e.g., Scott pi)

Ground "truth" Class

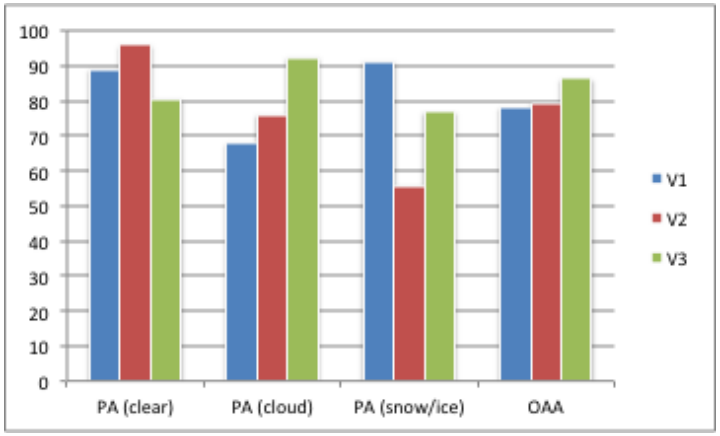
Classifier Class

Class	no Cloud (w)	Cloud	Sum	P A	E
NO CLOUD	8065	92	8157	98.9	1.1
CLOUD	2420	6495	8915	72.9	27.1
Sum	10485	6587	17072		
U A	76.9	98.6		OAA:	85.29
E	23.1	1.4			

Scotts Pi: 0.703

Krippendorfs alpha: 0.703

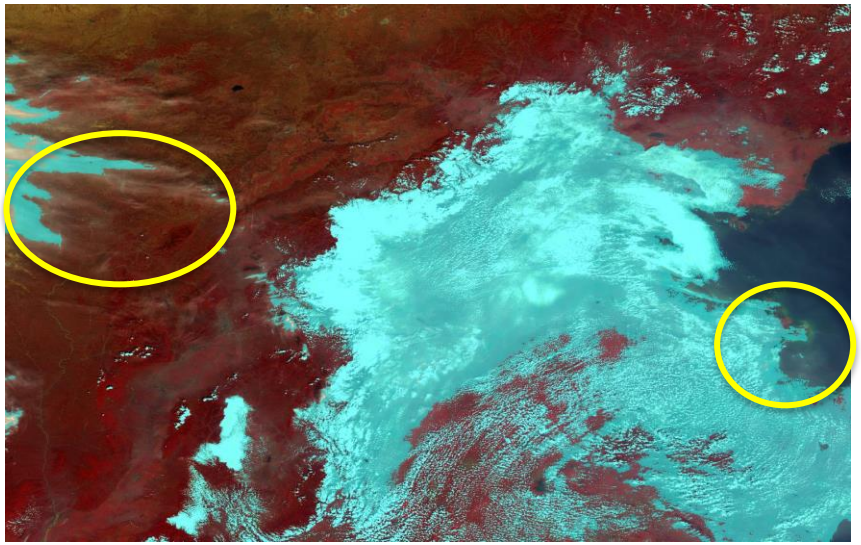
Cohens kappa: 0.708



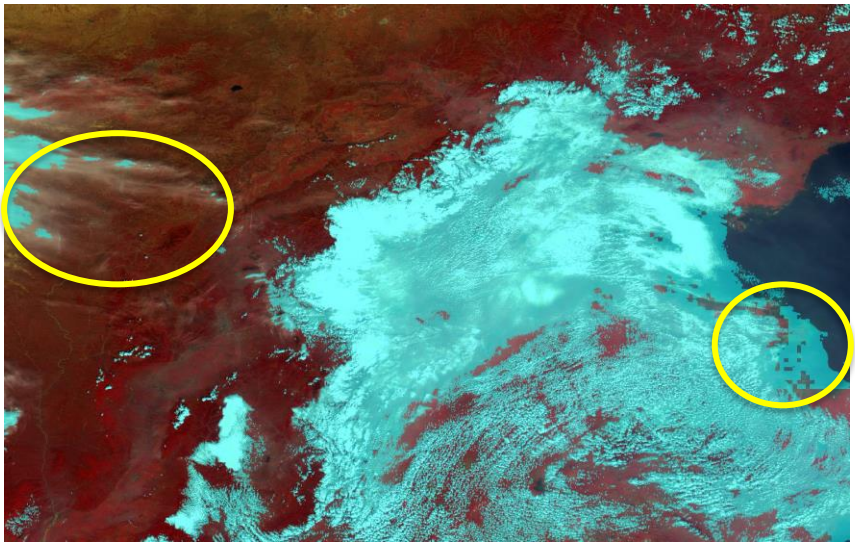
Quality Metrics 2: Visual inspection

- Visual inspection of RGB images is key to **complement** the per-pixel classification assessment since it provides the **contextual** information on surface heterogeneity and clouds texture
- Useful to identify limitations in clouds border delineation and for investigating semi-transparent clouds detection
- Metrics for comparison in such case are only qualitative

Cloud Mask 1



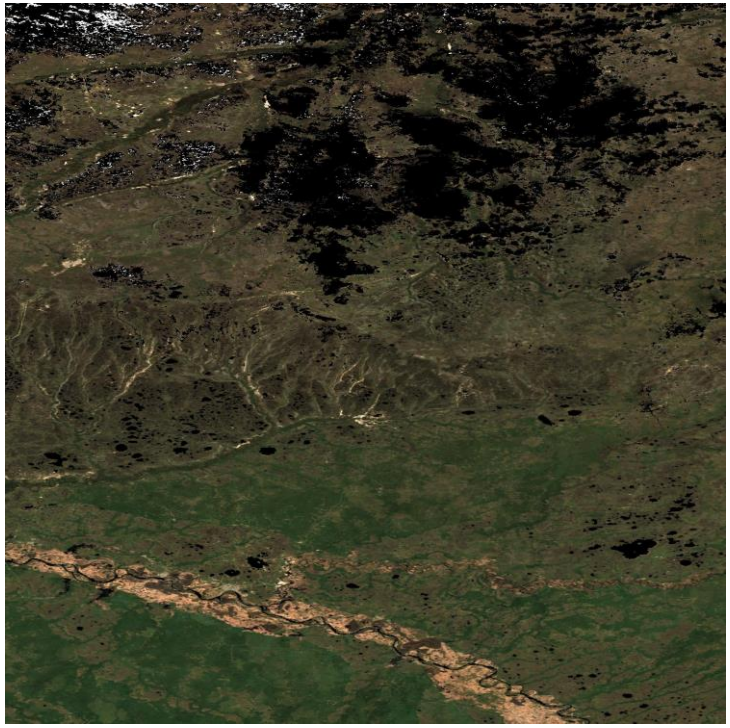
Cloud Mask 2



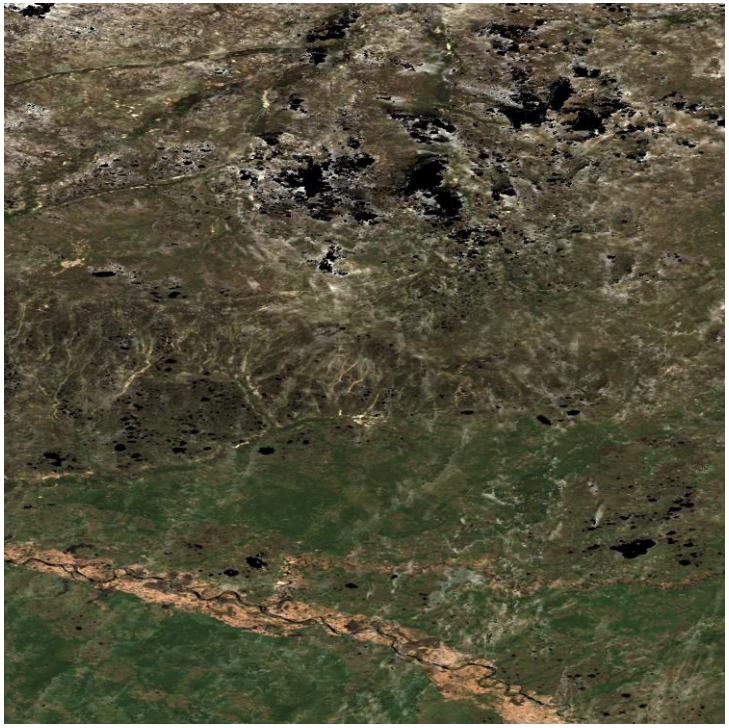
Quality Assessment 3: Composite Image inspection

- Inspection of L3 composite (mosaicking) images provide useful tool to identify artifacts or to investigate tolerance to cloud fraction
- Metrics for comparison include both visual (qualitative) and quantitative measures of spatial coherence (e.g., semi-variograms)

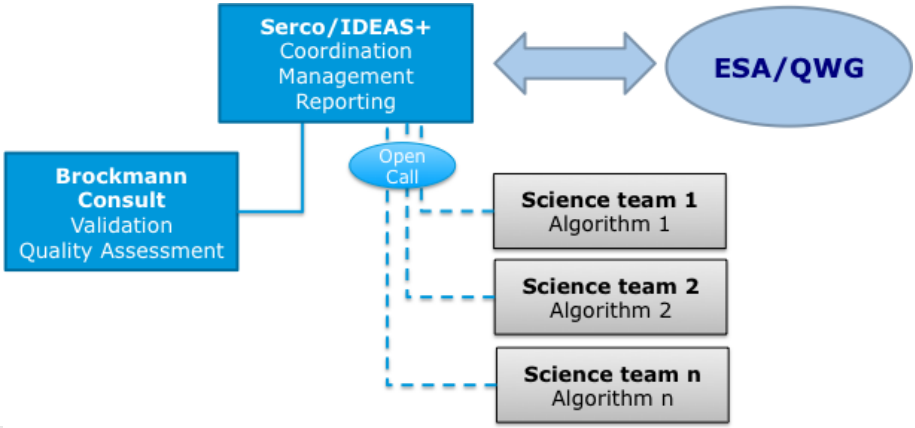
Clear-sky conservative

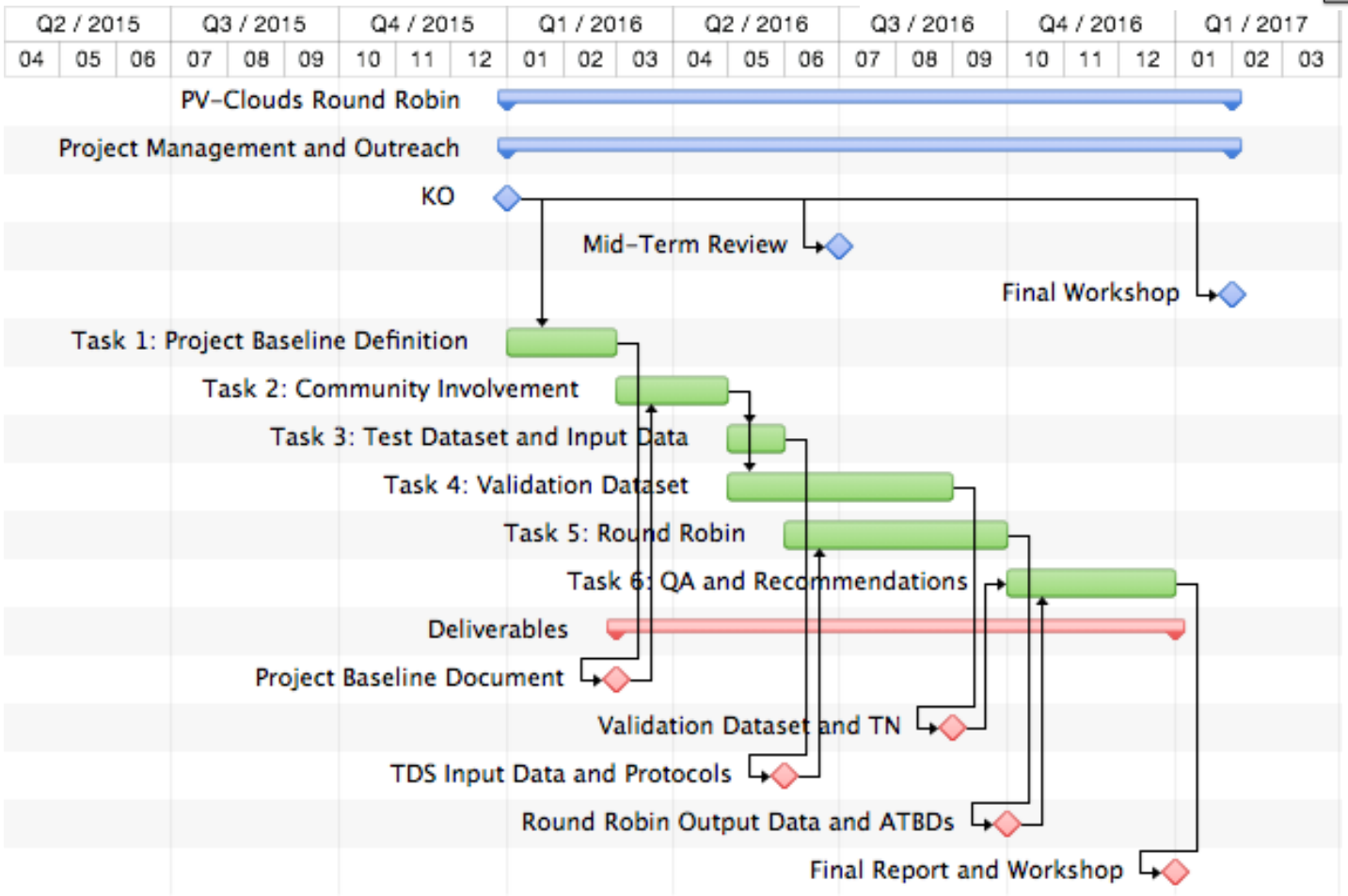


Cloud conservative



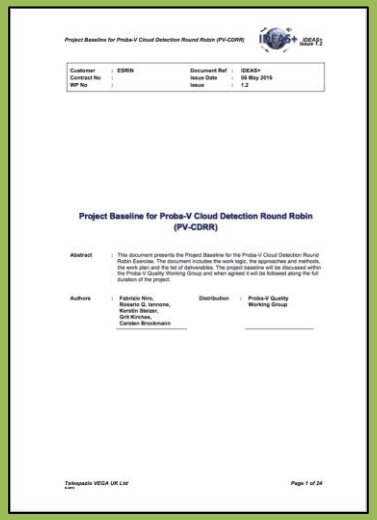
Organization and Schedule



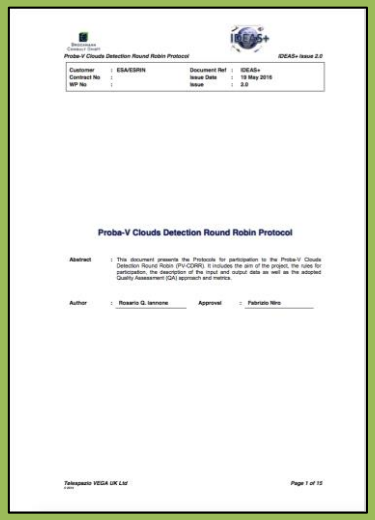


Deliverables

Baseline for the project (Feb 2016)


Project Baseline for Proba-V Cloud Detection Round Robin (PV-CDRR)

Round Robin Protocols (May 2016)


Proba-V Clouds Detection Round Robin Protocol

Project web-site (Feb 2016)

Input data in cloud toolbox (June 2016)

To be delivered:

- Validation Dataset Description (Oct 2016) – Brockmann
- ATBD and Cloud Mask (Nov 2016) – Algorithm providers
- Validation Report (Jan 2017) – Brockmann/Serco
- Final Workshop (Jan/Feb 2017)
- Conference proceeding/peer-reviewed paper (Feb/Mar 2017)

Participants

Participants	Institute (Country)	Legacy Method
Luis Gómez Chova	University of Valencia (Spain)	Probabilistic (MERIS/AATSR)
Clement Atzberger	University of Natural Resources and Life Science (Austria)	Neural Network (MODIS)
Ute Gangkofner	EoConsultancy (Austria)	Bayesian
Umberto Amato	National Research Council (Italy)	Statistical Discriminant Analysis (SEVIRI)
Alireza Taravat	Helmholtz Centre for Ocean Research (Germany)	Neural Network (SEVIRI)
Kevin Tansey	University of Leicester (UK)	Threshold (AATSR)
Rene Preusker	Free University of Berlin (Germany)	Bayesian (MERIS/AATSR)

Conclusion

- Proba-V cloud detection and masking is extremely **challenging** due limited spectral bands, lack of TIR and cirrus band
- **State-of-the-art algorithms** are participating to this inter-comparison exercise
- The results will be discussed in a final workshop and presented in a peer-reviewed paper
- Results are expected to **contribute to the advances** in the Proba-V operational processor and to provide useful **recommendations** for other optical missions S-3, S-2