PROBA-V CLOUD MASK VALIDATION

Validation Report

Version 1.0

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Abbreviations and Conventions

CLEAR	ProbaV Clear Mask
CLOUD	ProbaV Cloud Mask
OA	Overall Accuracy
PA	Producer's Accuracy
PV QWG	ProbaV Quality Working Group
SNOW/ICE	ProbaV Snow Ice Mask
SZA	Sun Zenith Angle
UA	User's Accuracy
VZA	Viewing Zenith Angle

1 Introduction

The scope of this document is to provide the results of the validation of the cloud screening of ProbaV. Three different versions were investigated in the framework of this investigation: Version 1.0; the initial cloud screening provided with the products delivered. After consultation of the ProbaV Quality Working Group (PV QWG), requirements for improvements were defined including a better detection of semi-transparent clouds and the need for the reduction of the cloud flag over bright surfaces; another issue concerned bright thick clouds, which were flagged as SNOW/ICE instead of CLOUD. In a version 2.0, which was presented during the last PV QWG meeting in February 2016, these issues were improved but the cloud detection was even too restrictive, and other issues were included. Therefore, with a third version – version 3.0 – VITO presented a cloud screening that was addressing all these issues and which is the current version and on which this report is focusing. During the validation process questions occurred concerning the cloud screening under certain viewing and sun azimuth conditions, which are also discussed in this report. Finally, the report provides in the end a recommendation and open points that should be addressed in the future.

2 Methods

The validation of the cloud screening is performed by two different approaches. The first one is a visual inspection of the cloud flags (and other pixel identification flags if available). Here, several images are investigated and between Version 1.0 and Version 3.0. The second approach is the PixBox validation, which is based on a database of manually selected and labelled surface pixels. This data base serves as reference data set which is compared to the classified images. The input and the reference data sets as well as the methods applied for assessing the ProbaV cloud mask is described in the following sections.

2.1 Testdata set

2.1.1 ProbaV

The products of four days covering the full globe have been selected as test data sets. The dates (21.03.2014, 21.06.2014, 21.09.2014 and 21.12.2014) represent 4 seasons and from these days a random subset was used for the pixel collection process. This data set has been processed for all investigated cloud screening versions (1.0, 2.0, 3.0). This report concentrates on the assessment of Version 3.0 in comparison to Version 1.0. The analyses are performed on the daily composited S1 TOA 300m products.

The outcome of the ProbaV cloud masking are the following categories:

- SM_FLAGS.CLEAR
- SM_FLAGS.UNDEFINED
- SM_FLAGS.CLOUD
- SM_FLAGS.SNOWICE
- SM_FLAGS.CLOUD_SHADOW
- SM_FLAGS.LAND

In the current version, no cloud shadow mask is provided.

2.1.2 Reference data set

The reference data set consist of a collection of manually collected pixels associated with expert knowledge labelled surface type. The tool developed and used for the collection and later the extraction of pixels is called PixBox. PixBox's goal is to gather relevant information from satellite images, collected on the basis of expert knowledge and experience, to characterise a specific pixel. The expert decides which of the pixels are to be considered, and then, based on his experience, assigns pre-defined properties (e.g., “completely cloudy”, " clear sky (land, water, snow/ice)", "semi-transparent clouds", "coastline") for each selected pixel. In a second level characterization it is specified if a turbid atmosphere comes from e.g. desert dust or fire or water surfaces are further characterized as turbid water, floating vegetation or sun glint. The pixels are only collected if the expert has no doubt in the determination of its properties. This can be the case due to the mosaicking of the ProbaV S1 products or unclear determination due to mixed pixels.

For the validation of the ProbaV Cloud Mask, 20000 pixels have been collected and labelled; Figure 1 shows the global distribution of these pixels. They cover the 4 days (seasonally distributed over the year), from which 50 tiles were selected randomly. For each tile approximately 100 pixels were selected. Figure 2 shows a small screenshot of a ProbaV RGB images and the position and labelling of collected pixels.

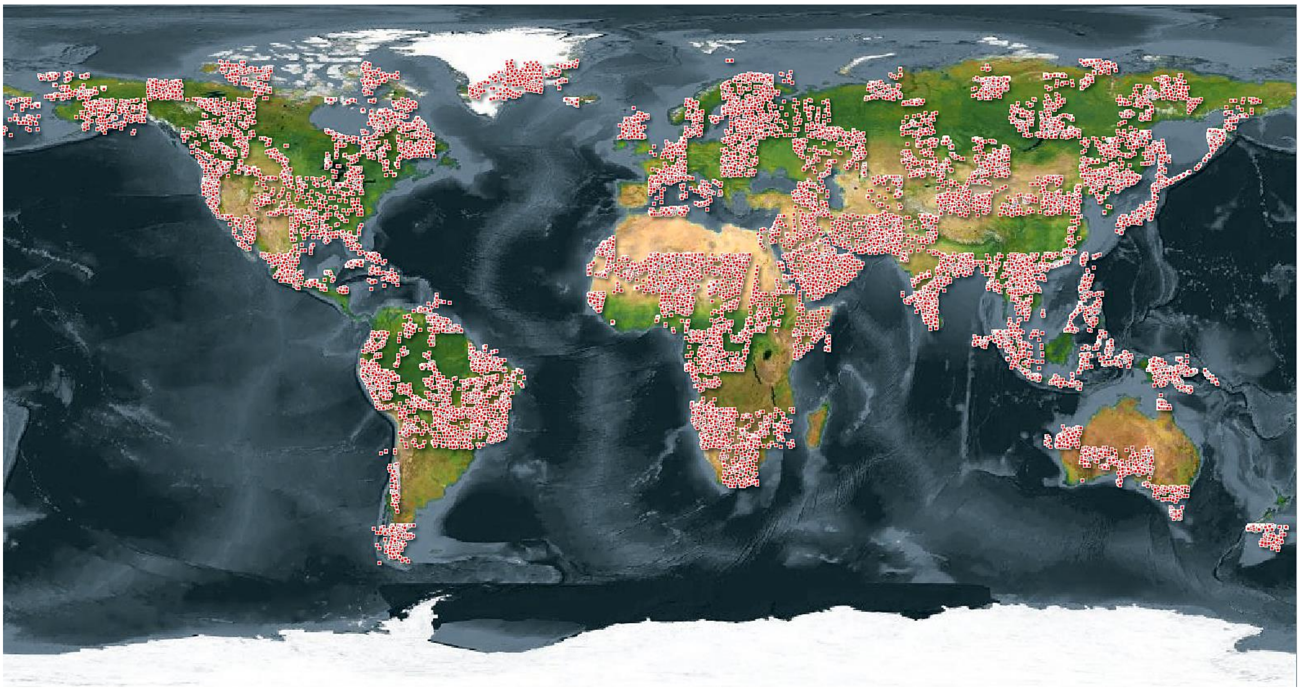


Figure 1: Position of globally collected pixels covering clear land, clear water, clear ice, totally cloud and semitransparent clouds.

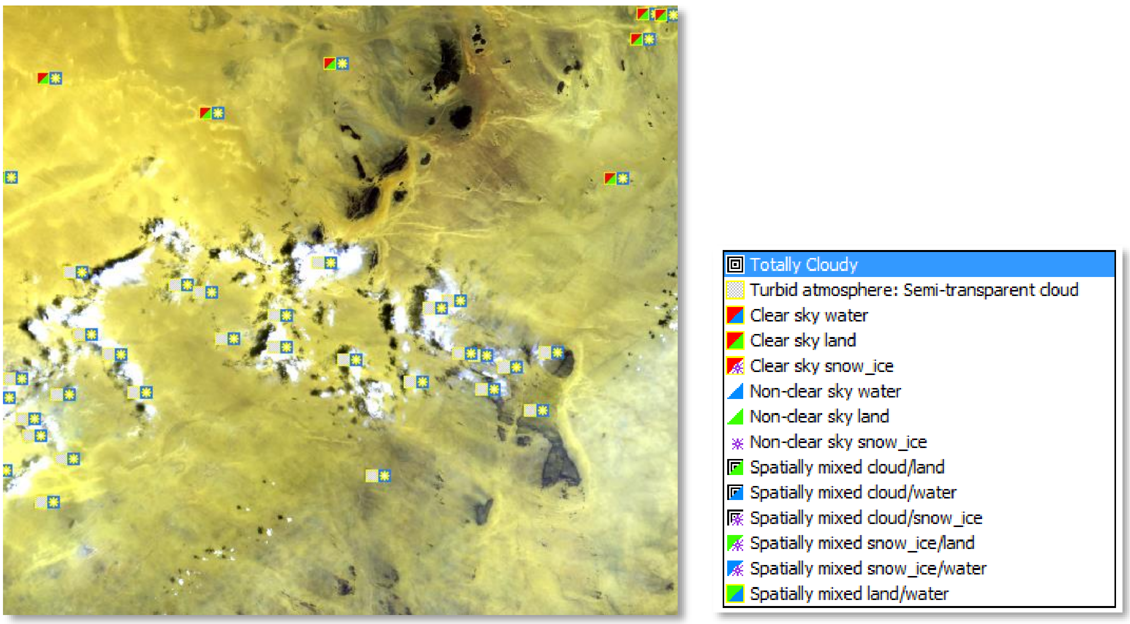


Figure 2: PixBox Validation data set collection tool.

The pixels are stored in a database with the assigned surface characteristic and the metadata derived from the respective products (such as pixel position, geolocation, date, time, viewing and sun angles, etc.). The tool window for labelling the pixels and the respective data base (subset) are displayed in Figure 3.

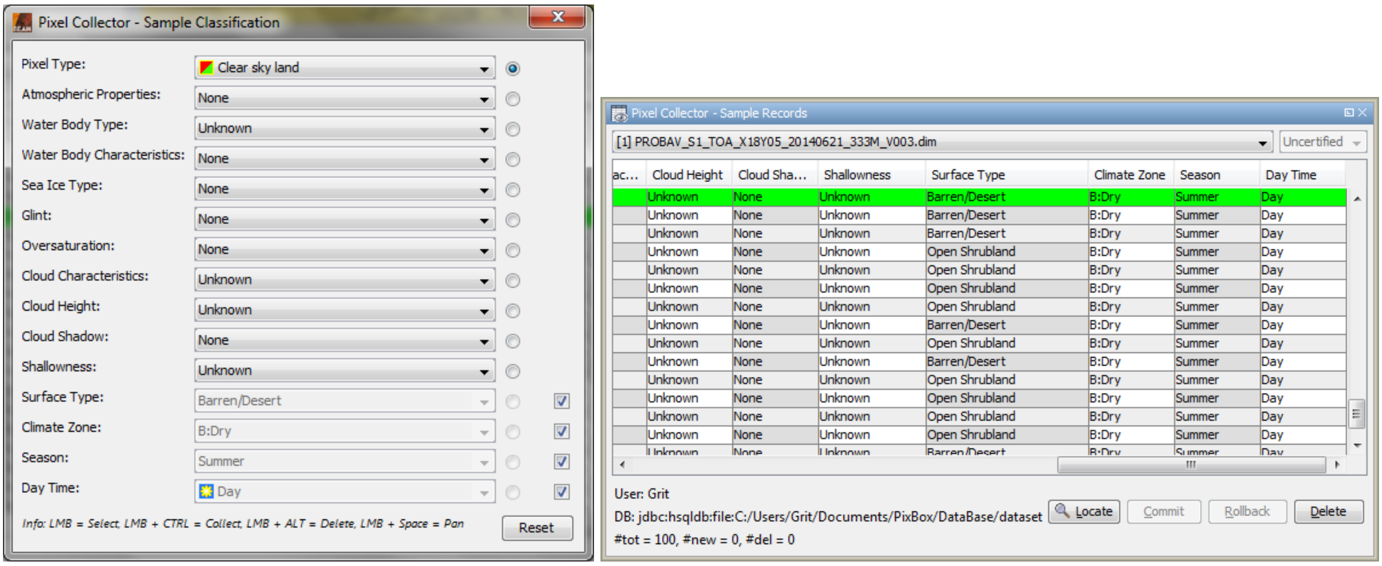
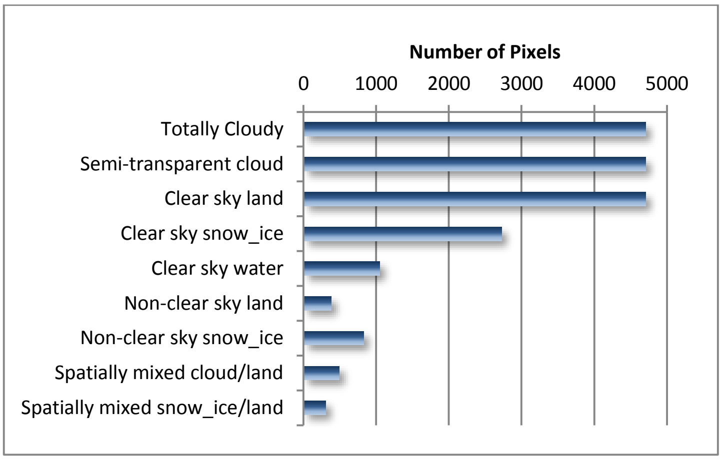


Figure 3: Tool window for labelling the pixels (left) and respective data base containing all pixels with surface category based on expert knowledge and meta-information (right).

The collection for the ProbaV Cloud Mask validation has the distribution of pixel types as listed in Table 1.

Table 1. Numbers of the collected pixels in the PixBox and respective distribution to surfaces

TOTAL	**20000**	**100.0%**
PIXEL TYPE	Number of pixels	Percentage
Totally Cloudy	4710	23.55%
Semi-transparent cloud	4710	23.55%
Clear sky land	4710	23.55%
Clear sky snow_ice	2729	13.65%
Clear sky water	1050	5.25%
Non-clear sky land	381	1.90%
Non-clear sky snow_ice	826	4.13%
Spatially mixed cloud/land	492	2.46%
Spatially mixed snow_ice/land	301	1.50%
Non-clear sky water	31	0.16%
Spatially mixed cloud/water	48	0.24%
Spatially mixed snow_ice/water	12	0.06%
SEASON		
Spring	5309	26.55%
Summer	4978	24.89%
Autumn	4691	23.45%
Winter	5022	25.11%
SURFACE TYPE		
Land	17537	87.68%
Water	2463	12.32%
of which Snow/Ice	3856	19.28%
of which Floating sea ice	401	2.01%



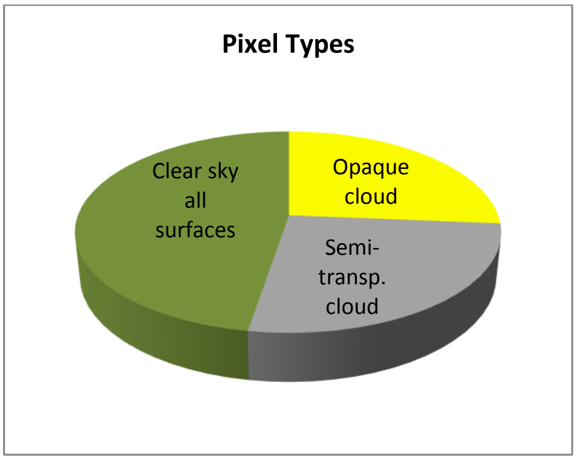
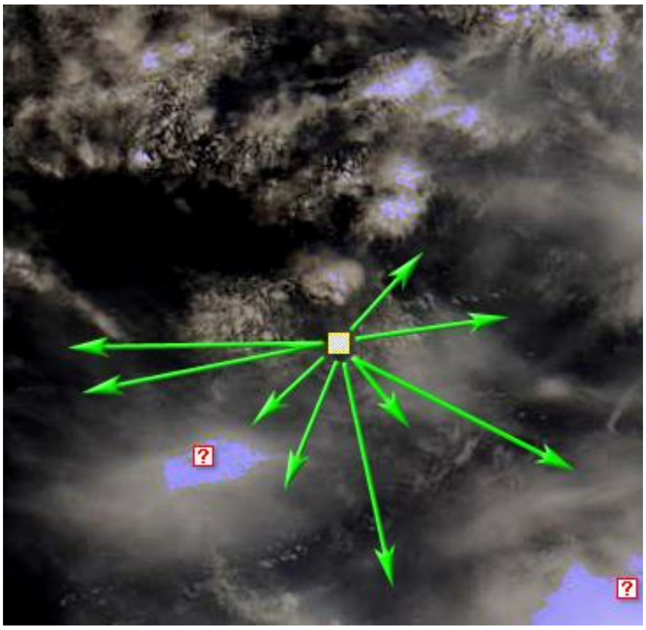
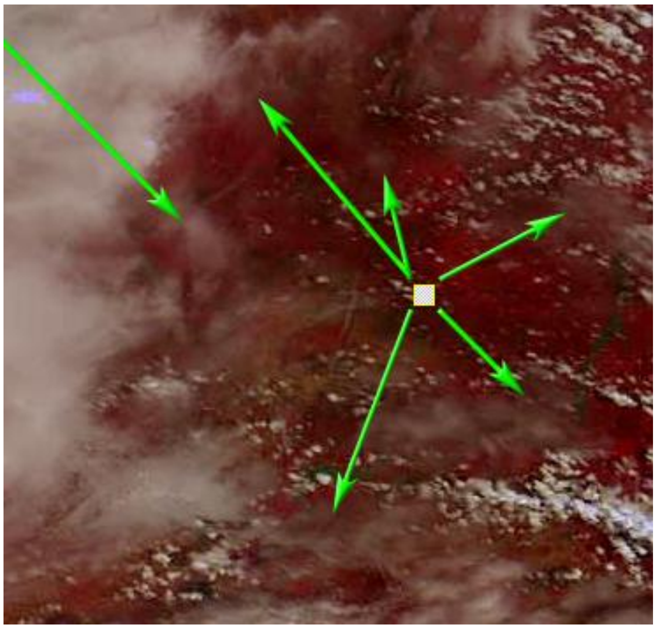


Figure 4: Distribution of surface types within the PixBox reference data set

For cloud detection, the clear cases are the easiest ones, which means that detecting an opaque cloud or clear land/water pixels. However, what makes the whole procedure more complicated are semitransparent clouds, through which the underlying surface is partly visible. They can have a very wide range of opaqueness and therefore, it is important to have a good definition of a semi-transparent cloud means. Within the PixBox pixel collection, all pixels that show influence by a cloud while the underlying surface is somehow visible. This is true for a wide range of pixels, [1]which means that within the semi-transparent cloud category, very different thickness of clouds is present.

WATER	LAND
	

1

Figure 5. Examples of semitransparent clouds over water and land surfaces showing the range of transparency; arrows pointing to extreme cases.

2.2 Visual inspection

The first assessment of the cloud masks has been performed by a visual inspection of the RGB images and overlaid cloud mask. This has been performed for the different versions that have been validated in order to assess the changes from one to the other version. In the end, Version 1.0 and Version 3.0 have been finally assessed.

The images are selected randomly from the reference data set provided by VITO. The images provide a very good first impression of the cloud screening and results are shown exemplarily for different surface types. However, as not all images can be investigated und all conditions, they should be regarded as examples and not all cases might be covered.

2.3 PixBox Validation

Reference data set based on expert knowledge has been generated in a pixel collection process, which is described in detail in section 2.1. Each new version of the cloud mask has been compared with this reference data set, which consists of 20000 pixels. This is performed by generating Confusion matrices which provide the following statistical measures:

- Overall accuracy
- Producer's accuracy by surface category defined in the reference data set
- Users' accuracy by pixel category received by the ProbaV Cloud masking
- Scott's Pi[2]
- Krippendorfs α[3,4]
- Cohens κ[5]

[2] Scott W., 1955, Reliability of content analysis: The case of nominal scale coding, Public Opinion Quarterly, 19: 321-325.
[3] Krippendorff K., 2004, Reliability in content analysis: some common misconceptions and recommendations, Human Communication Research 30.
[4] Krippendorff K., 2011, Computing Krippendorff''s alpha reliability, Annenberg School for Communication - Departmental Papers, University of Pennsylvania, (available online at: http://repository.upenn.edu/asc_papers/43/, accessed 22/03/2016).
[5] Cohen J., 1960, A coefficient of agreement for nominal scales. Educational and Psychological Measurement 20: 37–46.

Confusion matrices have been generated for different combination of the surface types and flags. Because the ProbaV Cloud mask has no extra class for semitransparent clouds, one confusion matrix was generated for totally clouds only, and another one were totally cloudy and semitransparent clouds were combined.

PV Cloud Mask	PixBox Category
CLOUD	Totally Cloudy
No CLOUD	Clear land, clear

PV Cloud Mask	PixBox Category
CLOUD	Totally Cloudy and semitransparent clouds
No CLOUD	Clear land, clear

Because in Version 1.0 of the ProbaV cloud mask thick clouds were identified as snow/ice pixels, one confusion matrix was also generated for assessing the CLOUD, CLEAR and SNOW flags. the SNOW/ICE flag was also investigated in a confusion matrix.

PV Cloud Mask	PixBox Category
CLOUD	Totally cloudy and semitransparent clouds
CLEAR	Clear sky land, clear sky water, clear sky ice
SNOW/ICE	Snow/Ice and floating sea ice

Finally, the different conditions where defined concerning the sun and viewing geometry for computing the confusion matrices.

- VZA & SZA > 50°
- VZA & SZA between 30 and 50°
- VZA & SZA < 30°

3 Results

3.1 Visual inspection

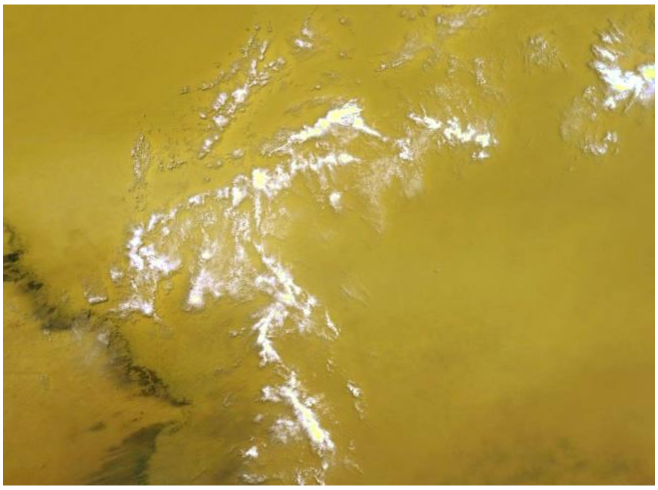
For assessing the ProbaV cloud mask visually, RGB images are generated and overlaid with the respective masks. The following examples show exemplarily triples of images (RGB, cloud mask version 1.0, cloud mask version 3.0) for illustrating the main findings.

- Clouds over bright surfaces
- Semi-transparent clouds

- Cloud borders
- Snow-ice flag and bright clouds
- Snow-ice surfaces
- Coastal waters & coastlines
- Turbid Water

This is followed by a section about the seasonal influence of the cloud masking which was observed during the visual inspection.

Clouds over bright surfaces I

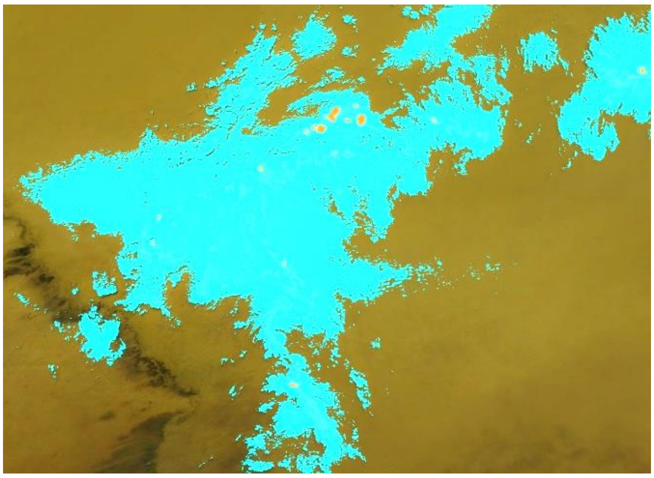


Findings:

While the cloud mask version 1.0 masks also clear pixels (over bright surfaces), version 3.0 captures well the clouds and semi-transparent clouds but is not flagging the clear bright pixels.

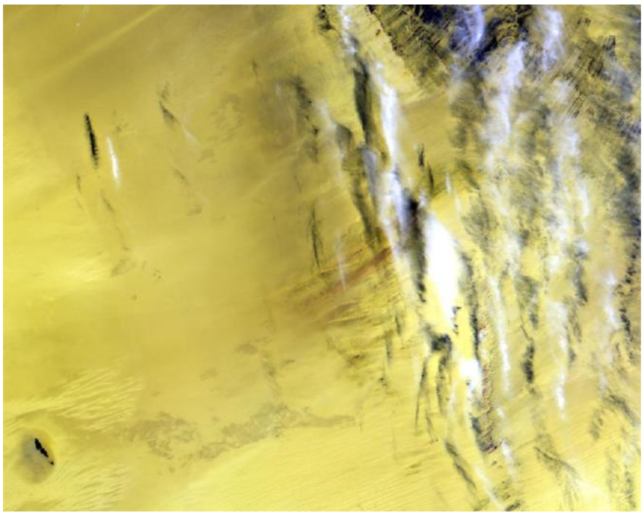
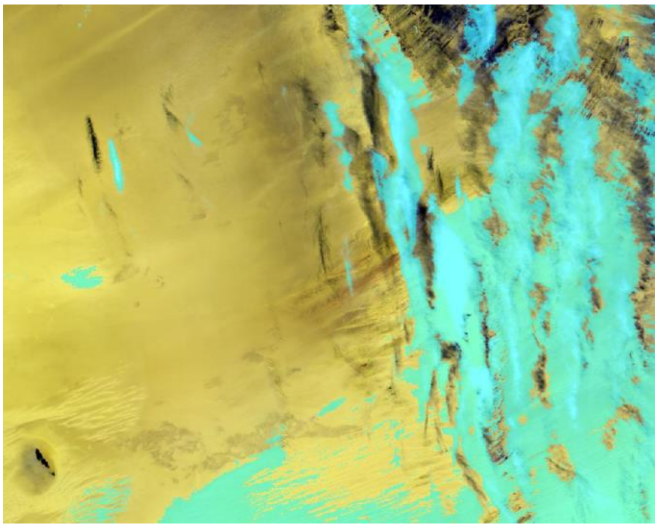
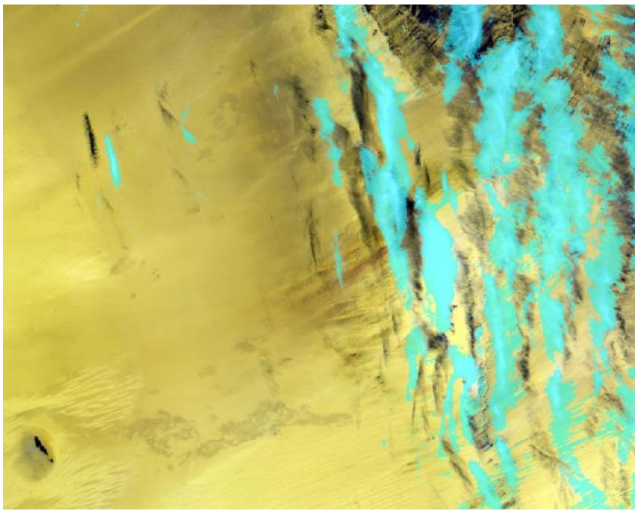
Tile: X17Y05

Date: 21.06.2014

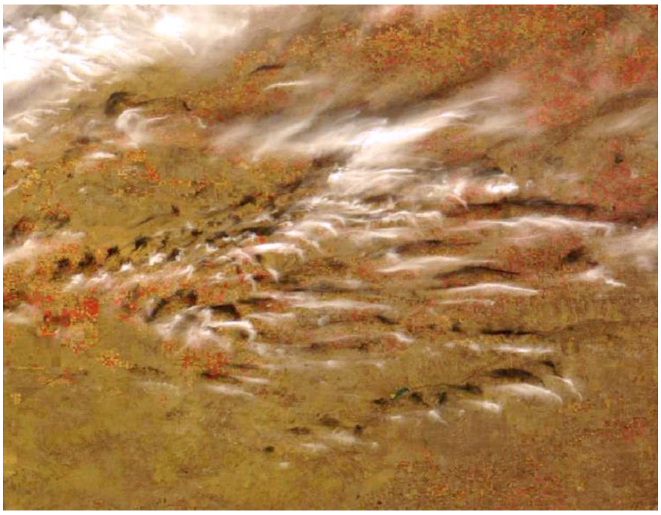


Version 1.0

Version 3.0

Clouds over bright surfaces II	
	Findings: Opaque clouds over bright surfaces are well captured in both versions. Version 3.0 is flagging less surfaces for semi-transparent clouds, but also clear surfaces are gained. Tile: X19Y05 Date: 21.12.2014
 **Version 1.0**	 **Version 3.0**

Semi-transparent clouds I

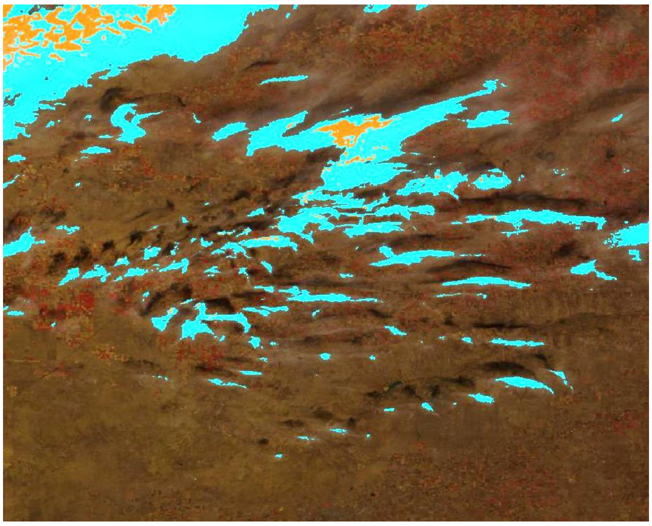


Findings:

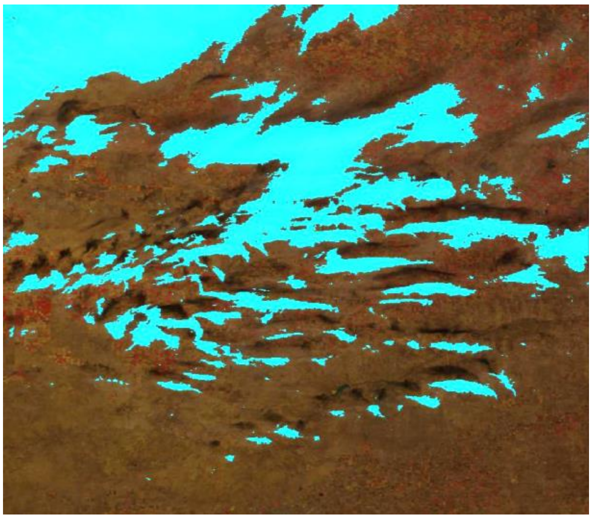
With Version 3.0 more semi-transparent clouds are flagged as cloud.

Tile: X07Y03

Date: 21.03.2014

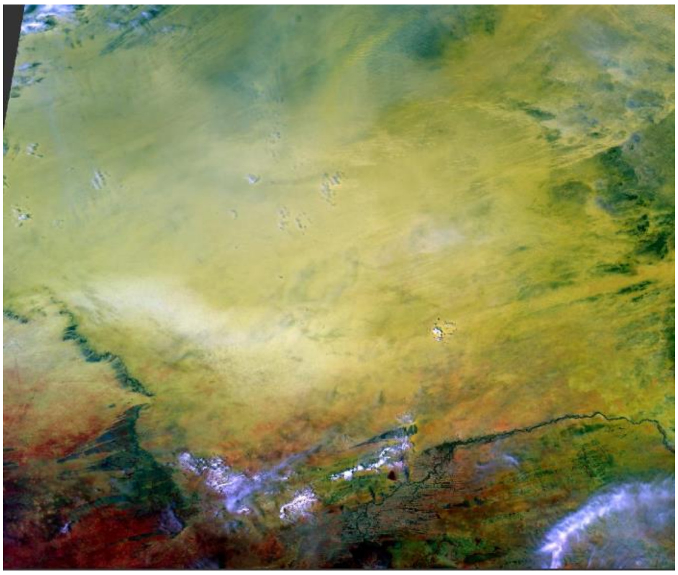


Version 1.0



Version 3.0

Semi-transparent clouds II

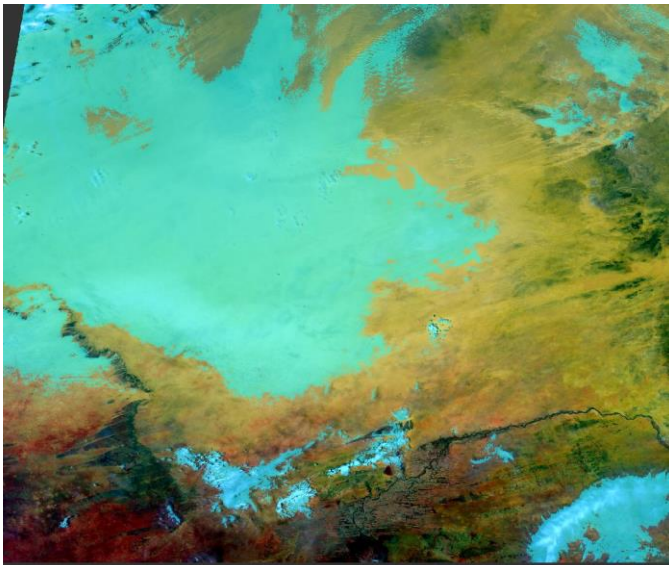


Findings:

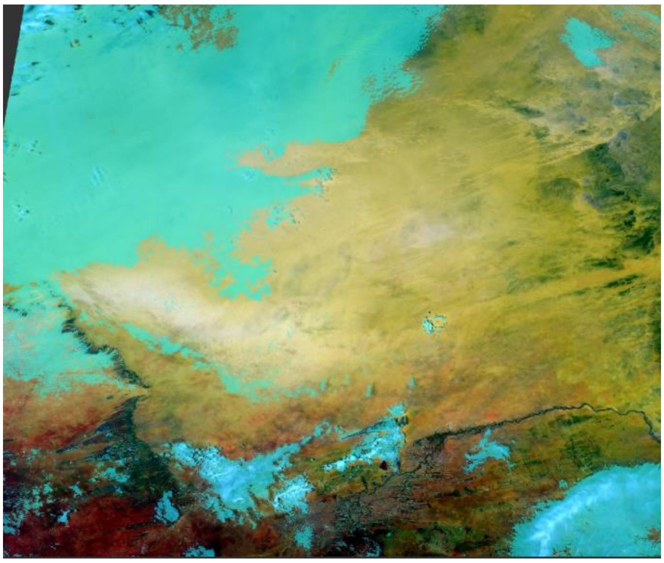
This product is challenging having semi-transparent clouds over bright surfaces. They are flagged as CLOUD in both versions, but less in Version 3.0. However, bright surfaces without overlaying clouds are gained.

Tile: X17Y05

Date: 21.09.2014

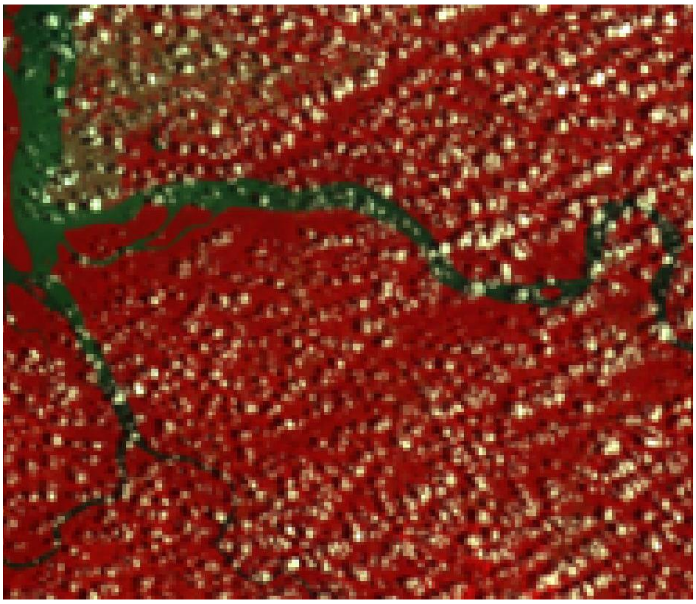


Version 1.0



Version 3.0

Cloud Borders

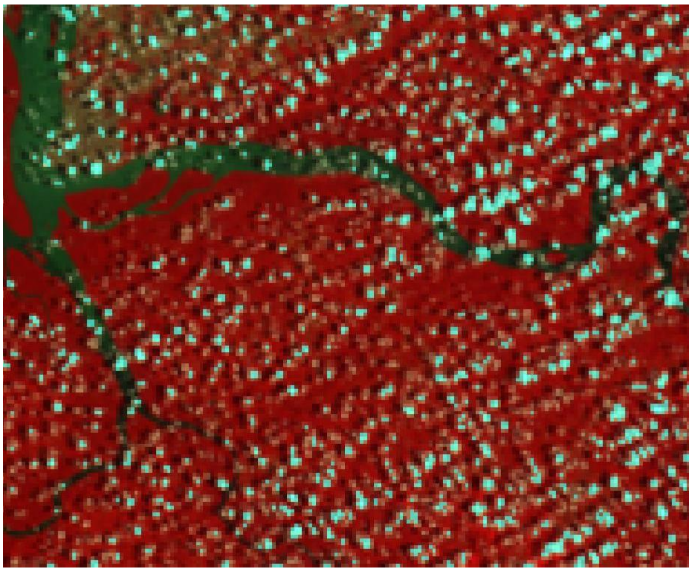


Findings:

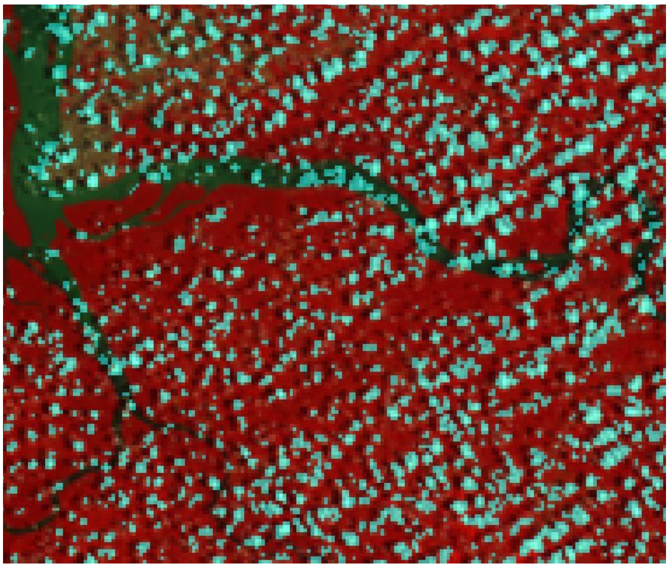
The cloud flag of Version 1.0 left out small clouds and cloud borders. This has been improved with Version 3.0; over land as well as over water.

Tile: X13Y07

Date: 21.09.2014

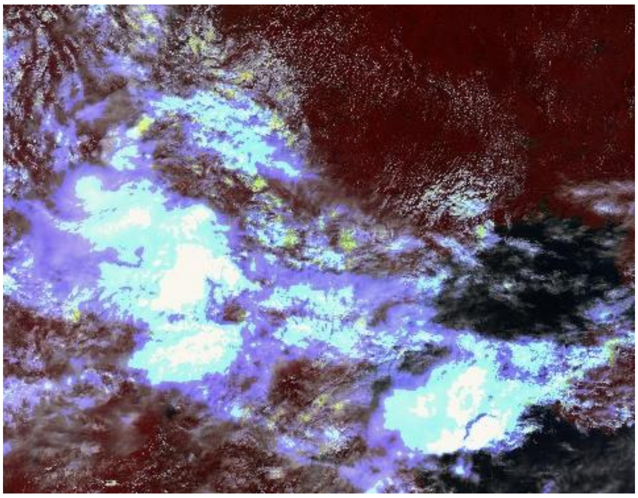


Version 1.0



Version 3.0

SNOW/ICE Flag and bright clouds

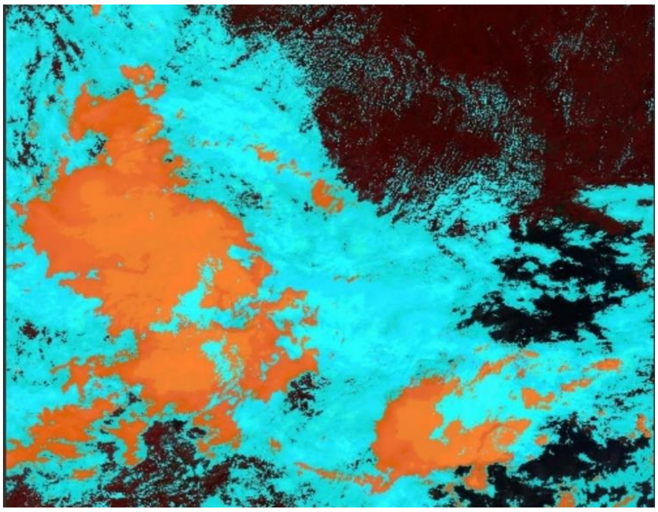


Findings:

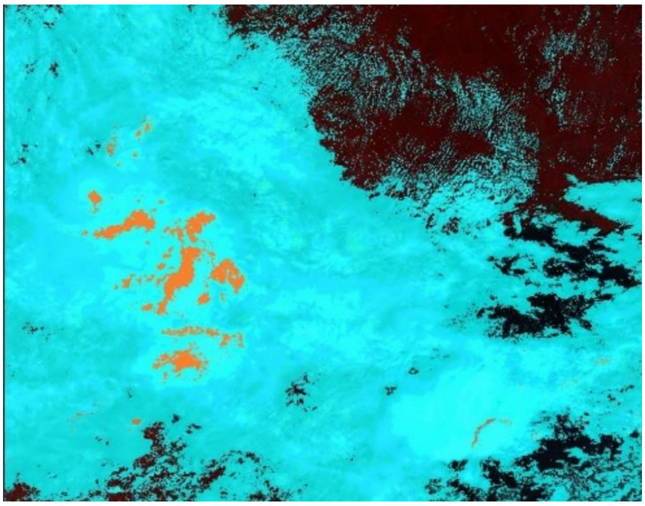
In Version 1.0 the problem occurred that thick clouds were flagged as SNOW/ICE (orange areas). This effect has been significantly reduced with Version 3.0. However, it still occurs in the central parts of very bright clouds.

Tile: X28Y05

Date: 21.09.2014

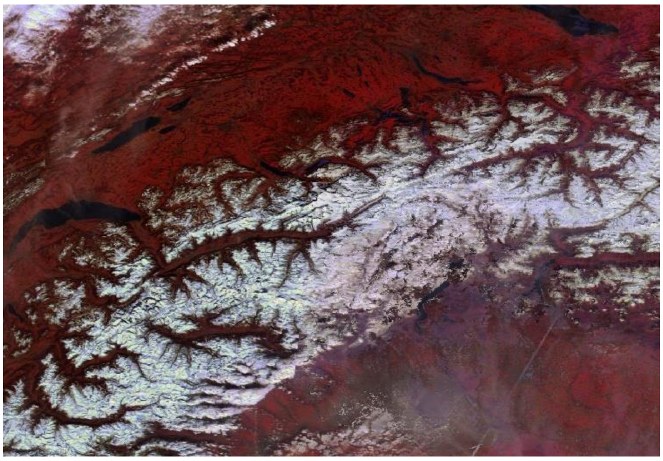


Version 1.0

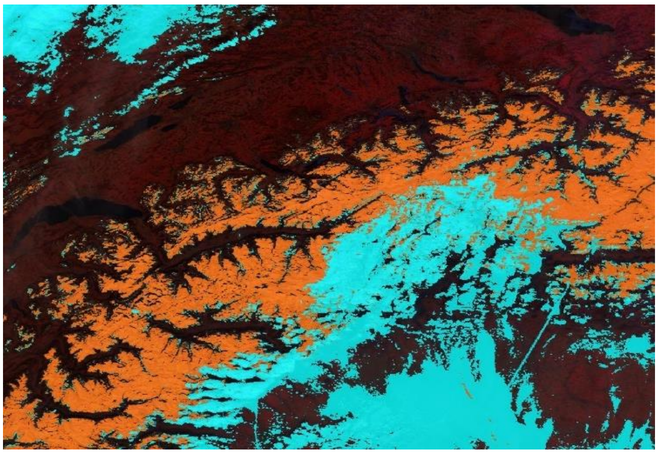
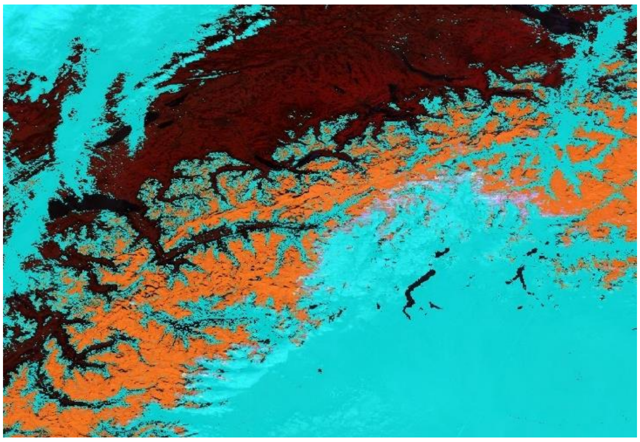


Version 3.0

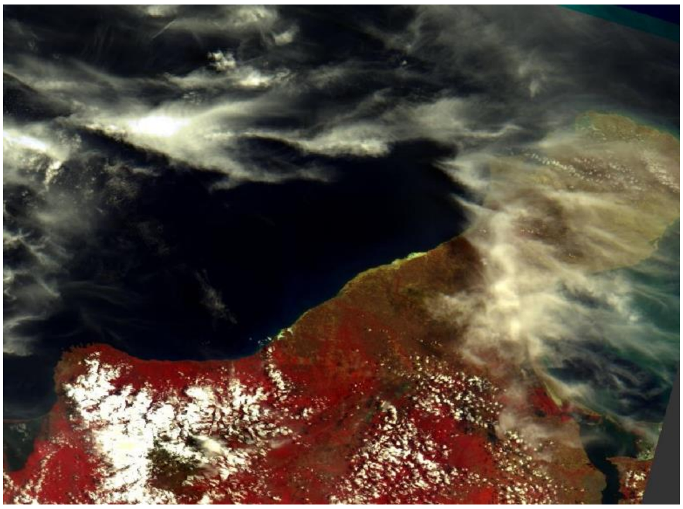
The remaining SNOW/ICE flagged pixels in the bright clouds seem to have a coincidence with the GOOD_NIR Flag, which is true in all the wrongly classified pixels, but which is also set in correctly classified CLOUD pixels. Thus, it is a reason but not a condition.

<table>
<tr><th colspan="2">SNOW/ICE Surfaces</th></tr>
<tr><td></td><td>Findings:

Mountainous areas with snow cover mixed with clouds have been very well captured by respective snow/ice (orange) and cloud flags in Version 1.0. In Version 3.0 the clear snow pixels are also well captured while clouds are often detected in the valleys, which were not cloud covered, while.

Tile: X18Y02
Date: 21.03.2014</td></tr>
<tr><td>
Version 1.0</td><td>
Version 3.0</td></tr>
<tr><td colspan="2"></td></tr>
</table>

Water Surfaces

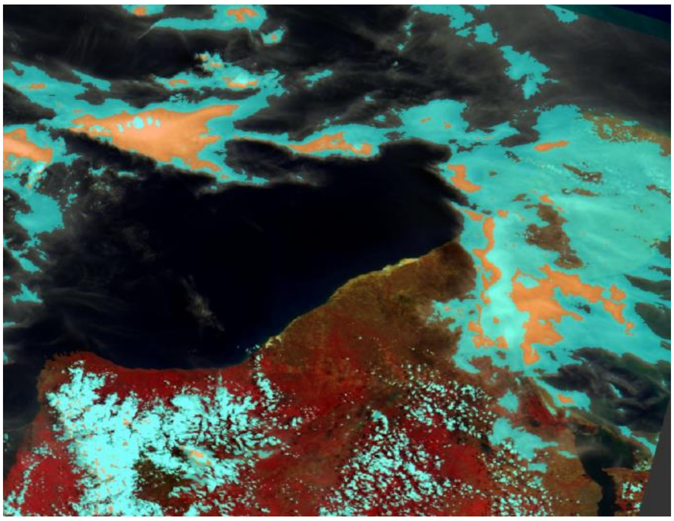


Findings:

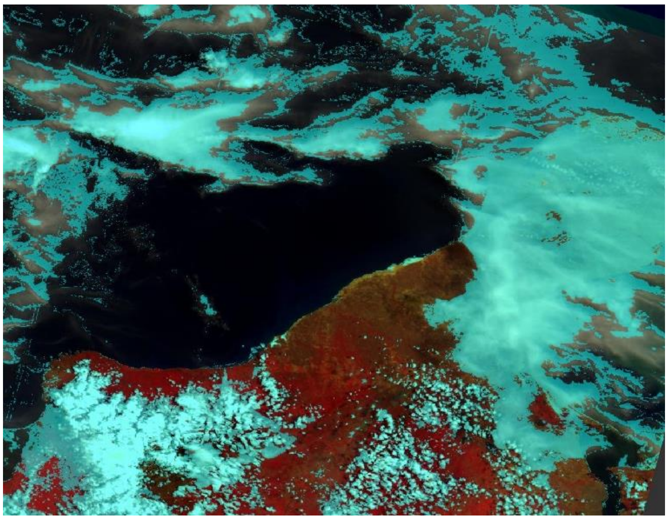
This example shows the introduction of artefacts in the clouds over water and wrongly classified CLOUD flag along the coastline with Version 3.0. Version 1.0 is also influenced by the misclassification of snow/ice (not in the focus here).

Tile: X10Y06

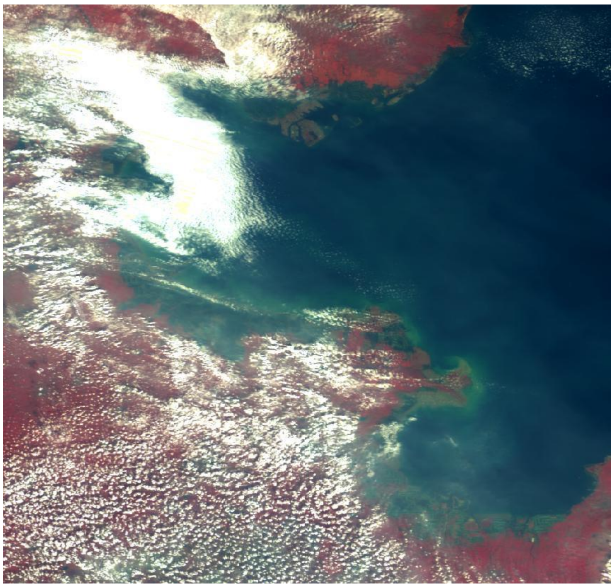
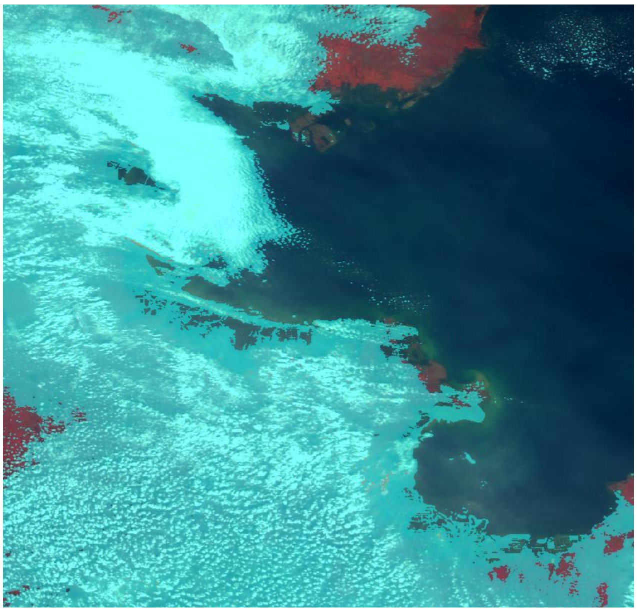
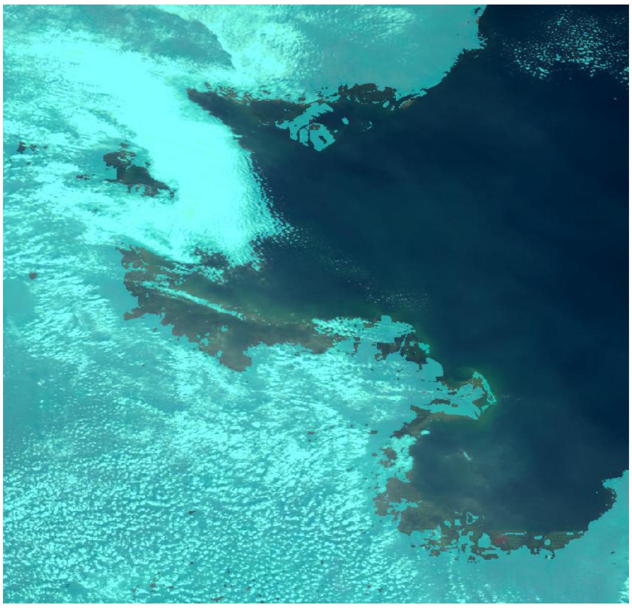
Date: 21.06.2014



Version 1.0



Version 3.0

Turbid Water	
	Findings: Version 1.0 flagged turbid water pixels as cloud, while version 3.0 improves for turbid waters. Tile: X29Y03 Date: 21.09.2014
 **Version 1.0**	 **Version 3.0**

3.2 Confusion matrices

The results of the confusion matrices reflect what could be detected in the images. The matrices are shown for Version 1.0 in Figure 6 and for Version 3.0 in Figure 7. The overall accuracy of Version 3.0 increases compared to Version 1.0. In detail, the differences are: the CLOUD flag captures more Clouds, which is mainly due to a better detection of semi-transparent clouds and because the bright and thick clouds are gained from the former SNOW/ICE flag (PA increases from 83 to 95.2% for clouds). On the other side, clear pixels are lost and flagged in Version 3.0 as CLOUD (PA reduces from 90.5 to 80.8% for clear surfaces).

ProbaV Cloud Classification Version 1.0 - all surfaces (clouds+semitrans)

In-Situ Database

ProbaV

Class	Clear	Clo+Semi	Sum	U A	E
CLEAR	4986	1298	6284	79.3	20.7
CLOUD	525	6345	6870	92.4	7.6
Sum	5511	7643	13154		
P A	90.5	83.0		OAA:	86.14
E	9.5	17.0			

Scotts Pi: 0.719

Krippendorfs alpha: 0.719

Cohens kappa: 0.72

Figure 6: Confusion matrix for the Cloud Classification Version 1.0. Clouds comprise totally cloudy and semitransparent clouds.

ProbaV Cloud Classification Version 3.0 - all surfaces (clouds+semitrans)

In-Situ Database

ProbaV

Class	Clear	Clo+Semi	Sum	U A	E
CLEAR	4438	440	4878	91.0	9.0
CLOUD	1052	8644	9696	89.2	10.8
Sum	5490	9084	14574		
P A	80.8	95.2		OAA:	89.76
E	19.2	4.8			

Scotts Pi: 0.776

Krippendorfs alpha: 0.776

Cohens kappa: 0.777

Figure 7: Confusion matrix for the Cloud Classification Version 3.0. Clouds comprise totally cloudy and semitransparent clouds.

When regarding only the category of semi-transparent clouds, it becomes clear from Figure 8 that in Version 3.0 91.9% of the semi-transparent clouds are flagged as CLOUD. It should not the goal to reach 100% here, as semi-transparent clouds can be very thin and it depends on the subsequent processing if they need to be detected or not. And the detection of semi-transparent clouds is always a trade-off with loosing clear pixels when classified as CLOUD. This can be seen in Figure 9, where the percentage of clear pixels classified as CLOUD increases from 9.5% in Version 1.0 to 19.2% in Version 3.0. Note that Figure 9 covers all cloud pixels, while Figure 8 is only focusing on the semi-transparent clouds.

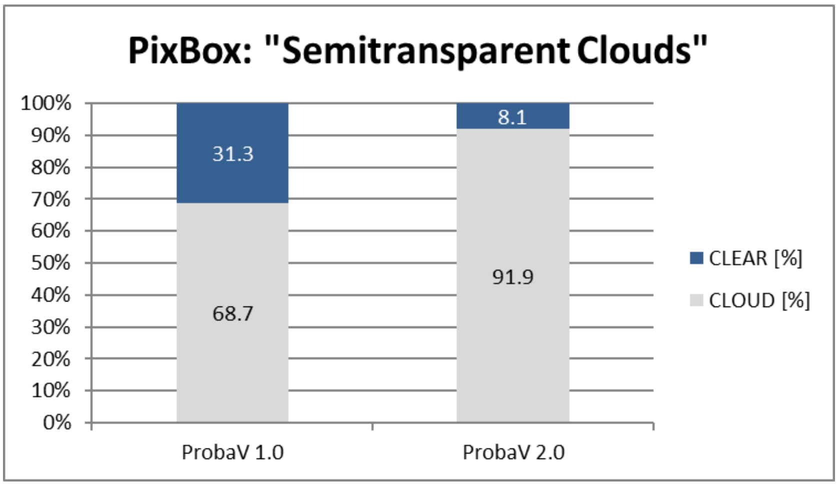


Figure 8: Percentage of the semi-transparent clouds classified as CLOUD or CLEAR in Version 1.0 and Version 3.0

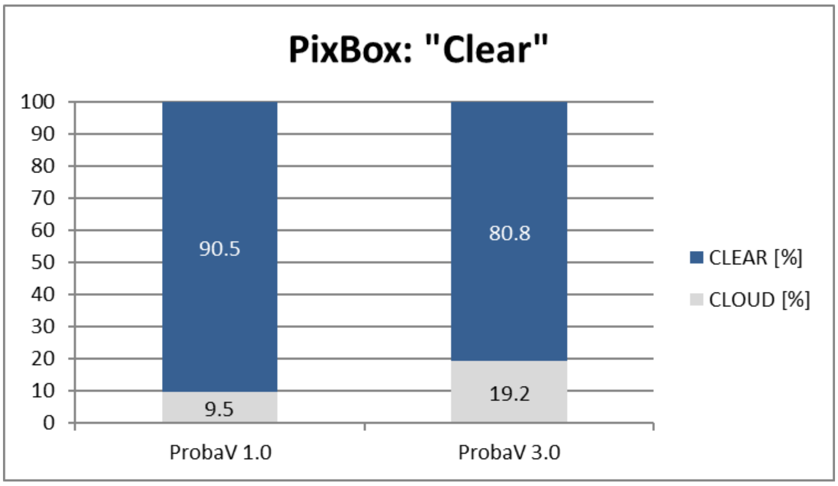


Figure 9: Percentage of the clear pixels classified as CLEAR or CLOUD in Version 1.0 and Version 3.0

Because the SNOW/ICE flag was an issue within Version 1.0, it is shown in Figure 10 and Figure 11. The User's Accuracy increases from 57.7% to 87.4% and this is mainly achieved by the significant reduction of wrongly classified Cloud pixels as SNOW/ICE from 1695 to 270 pixels. The Producer's Accuracy decreases from 91.2% to 76.8% due to snow/ice pixels that are classified as CLOUD in Version 3.0.

ProbaV Cloud Classification Version 1.0 - all surfaces

In-Situ Database

Class	Clear	Clo+Semi	Snow/Ice	Sum	U A	E
CLEAR	4986	1298	201	6485	76.9	23.1
CLOUD	525	6345	35	6905	91.9	8.1
SNOW/ICE	93	1695	2436	4224	57.7	42.3
Sum	5604	9338	2672	17614		
P A	89.0	67.9	91.2		OAA:	78.16
E	11.0	32.1	8.8			

ProbaV

Scotts Pi: 0.654

Krippendorfs alpha: 0.654

Cohens kappa: 0.658

Figure 10: Confusion matrix for the Cloud Classification Version 1.0 for clear, clouds and snow/ice pixels. Clouds comprise totally cloudy and semitransparent clouds.

ProbaV Cloud Classification Version 3.0 - all surfaces

In-Situ Database

Class	Clear	Clo+Semi	Snow/Ice	Sum	U A	E
CLEAR	4438	440	111	4989	89.0	11.0
CLOUD	1052	8644	509	10205	84.7	15.3
SNOW/ICE	25	270	2050	2345	87.4	12.6
Sum	5515	9354	2670	17539		
P A	80.5	92.4	76.8		OAA:	86.28
E	19.5	7.6	23.2			

ProbaV

Scotts Pi: 0.762

Krippendorfs alpha: 0.762

Cohens kappa: 0.763

Figure 11: Confusion matrix for the Cloud Classification Version 3.0 for clear, clouds and snow/ice pixels. Clouds comprise totally cloudy and semitransparent clouds.

Figure 12: Illustrates in another way how the SNOW/ICE flag and CLOUD flag change between Version 1.0 and Version 3.0. When the reference data set indicates Snow/Ice, in Version 3.0 almost 20% of the pixels are classified as CLOUD which means that we lose correctly classified snow/ice pixels. But in the other direction, 88.7% of all SNOW/ICE flagged pixels are really snow/ice in Version 3.0; in Version 1.0 this was only 67%.

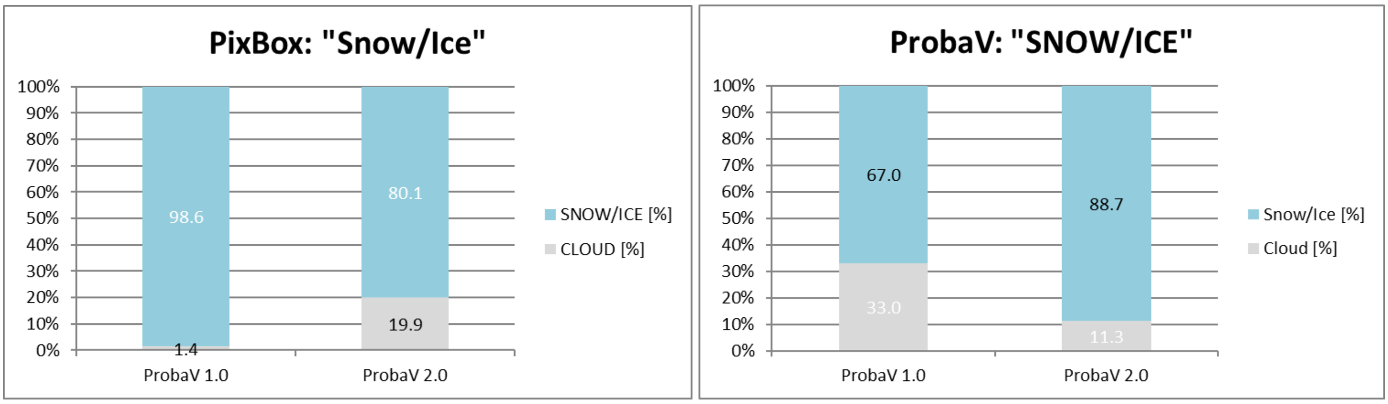


Figure 12: Comparison of the relationship of the SNOW/ICE and CLOUD flags in Version 1.0 and Version 3.0

3.3 Investigation of sun and viewing geometry

It was observed that the performance of the cloud detection might depend on the sun and viewing geometry and thus the air mass to be passed. Together with high zenith angles (SZA and VZA), turbid atmosphere or bright surfaces in addition may cause the overestimation of clouds.

Hereafter, analyses have been performed to investigate the effect of sun and viewing angles.

The following image pairs demonstrate that the cloud screening performs well under small zenith angles (first row Figure 13 and Figure 15). The two examples are chosen for bright surfaces (Figure 13) and dark surfaces (Figure 15). The second row of the respective example shows the same tile for another day and therefore acquired under a different geometry: large SZA and large VZA. It is clearly seen that the CLOUD flag has a much larger extend than the cloud, thus many clear pixels are flagged as CLOUD. The images below show the areas with VZA and SZA > 45° in violet and red colour. They only occur in the second example of the respective tile.

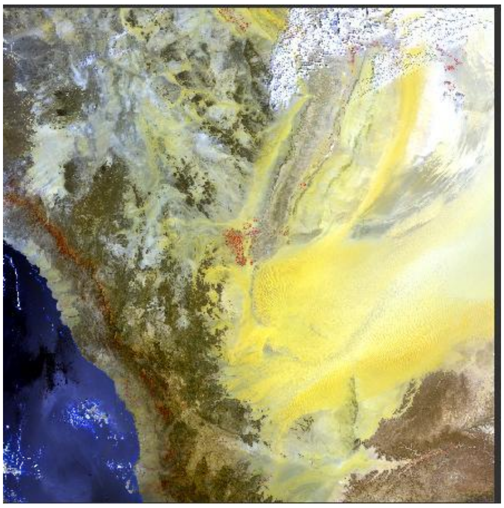
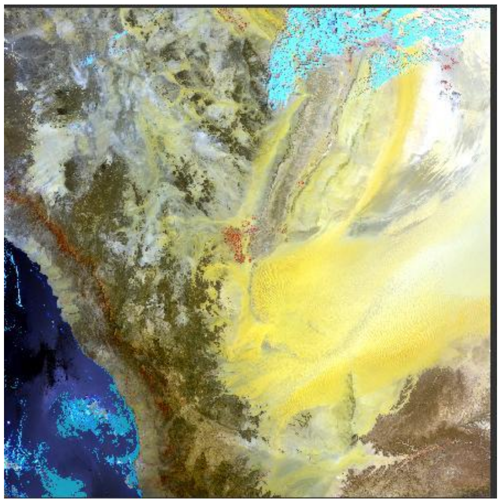
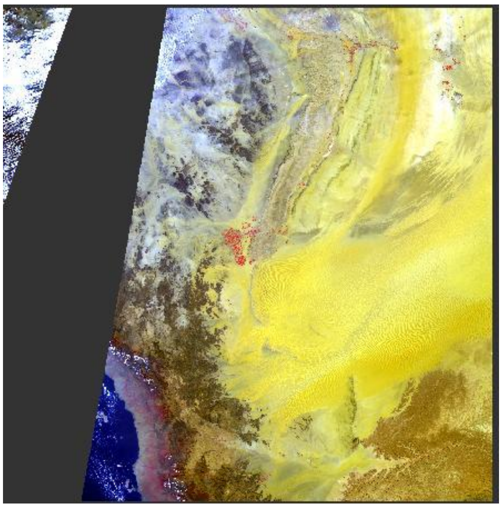
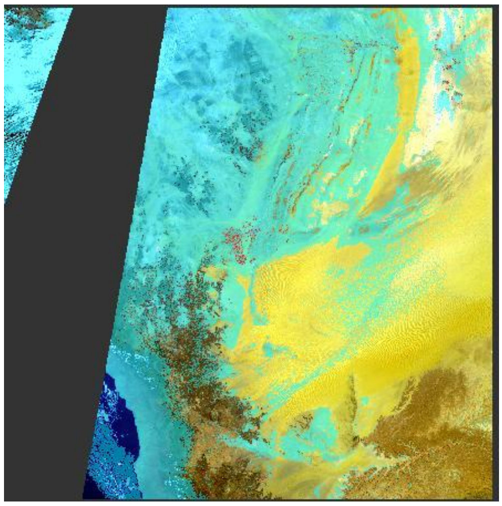
Month	RGB	Cloud Mask Version 3.0
Small SZA and VZA (21.03.2014)		
Large SZA and VZA (21.12.2014)		

Figure 13: Cloud Masks of Tile X22Y05 for 21.03.2014 and 21.12.2014 under different geometric conditions (example bright surfaces)

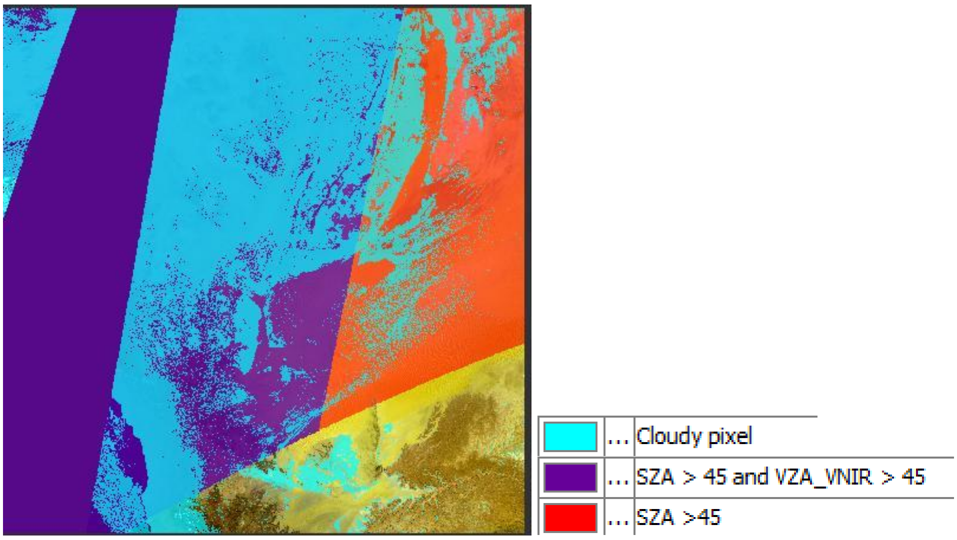


Figure 14: Areas where SZA and VZA are larger than 45° for the image 21.12.2014, X22Y05

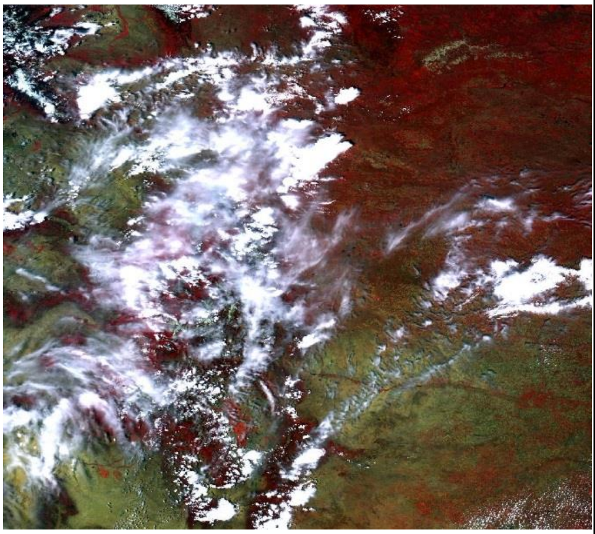
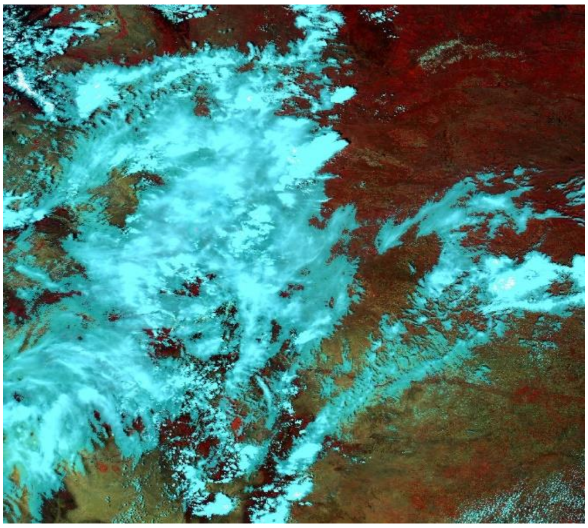
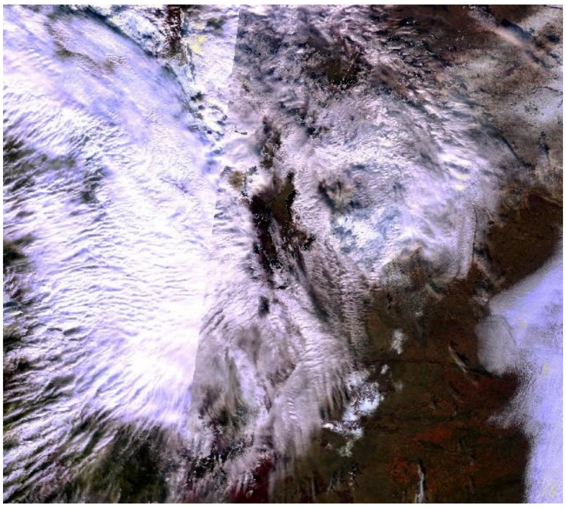
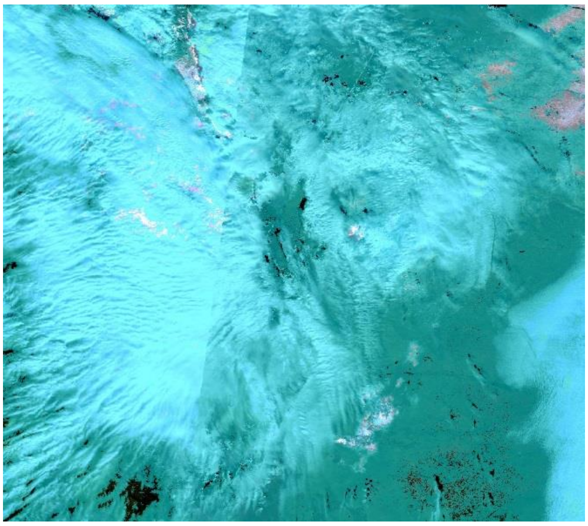
Month	RGB	Cloud Mask Version 3.0
Small SZA and VZA (21.03.2014)		
Large SZA and VZA (21.12.2014)		

Figure 15: Cloud Masks of Tile X07Y03 for 21.03.2014 and 21.12.2014 under different geometric conditions (example bright surfaces)

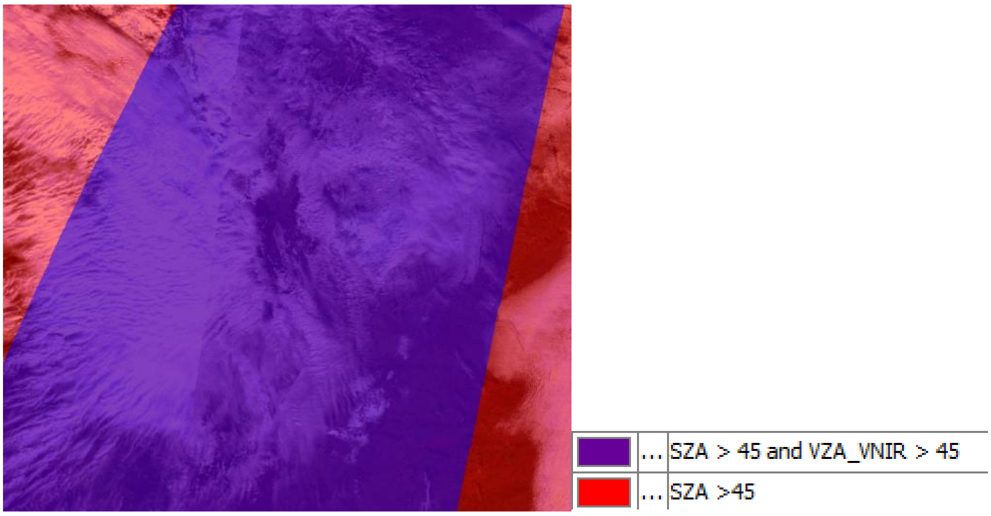


Figure 16: Areas where SZA and VZA are larger than 45° for the image 21.12.2014, X07Y03 (cloud flag left in order to ease the image)

Confusion matrices and related statistics have been produced for different categories in dependency of the viewing and sun viewing angles (Figure 17 - Figure 19). A trend can be observed that with larger angles more clear pixels are classified as CLOUD, which has already been observed in the visual inspection of the images. As a consequence, the Overall Accuracy decreases from the smaller to the larger zenith angles and a decrease of the Producer's Accuracy for clear surfaces and an increasing Producer's Accuracy for cloudy pixels.

ProbaV Cloud Classification Version 3.0 - small SZA & VZA < 30

In-Situ Database

ProbaV

Class	Clear	Clo+Semi	Sum	U A	E
CLEAR	832	69	901	92.3	7.7
CLOUD	104	1251	1355	92.3	7.7
Sum	936	1320	2256		
P A	88.9	94.8		OAA:	92.33
E	11.1	5.2			

Scotts Pi: 0.841

Krippendorfs alpha: 0.841

Cohens kappa: 0.841

Figure 17: Confusion matrix for pixels with a SZA and VZA smaller than 30°

ProbaV Cloud Classification Version 3.0 - medium SZA & VZA between 30 and 50

In-Situ Database

ProbaV

Class	Clear	Clo+Semi	Sum	U A	E
CLEAR	631	27	658	95.9	4.1
CLOUD	164	811	975	83.2	16.8
Sum	795	838	1633		
P A	79.4	96.8		OAA:	88.3
E	20.6	3.2			

Scotts Pi: 0.763

Krippendorfs alpha: 0.763

Cohens kappa: 0.764

Figure 18: Confusion matrix for pixels with a SZA and VZA between 30° and 50°

ProbaV Cloud Classification Version 3.0 - large SZA & VZA > 50

In-Situ Database

ProbaV

Class	Clear	Clo+Semi	Sum	U A	E
CLEAR	50	2	52	96.2	3.8
CLOUD	143	536	679	78.9	21.1
Sum	193	538	731		
P A	25.9	99.6		OAA:	80.16
E	74.1	0.4			

Scotts Pi: 0.289

Krippendorfs alpha: 0.289

Cohens kappa: 0.333

Figure 19: Confusion matrix for pixels with a SZA and VZA larger than 50°

The following figures (Figure 20 - Figure 22) summarize the finding for the most effected measures of the confusion matrices for both, Version 1.0 and Version 3.0. While the first three groups in each figure show the values for the different geometries, the last one is providing the values for all pixels. In general, these figures show the poorer performance for the high angle cases; however, the effect is more distinct for the cloud detection of Version 3.0. The most obvious influence can be seen in the Producer's Accuracy for Clear Surfaces, which is depicted in Figure 21. It increases from 25.9% for large angles to 88.9% for small angles (Version 3.0) and from 60% to 91.7% for Version 1.0. The measures Scott's Pi, Krippendorf's α and Cohen's κ show the same tendency, ranging from 0.29 to 0.84 for Version 3.0 and from 0.6 to 0.84 for Version 1.0 (Figure 22, Krippendorf's α).

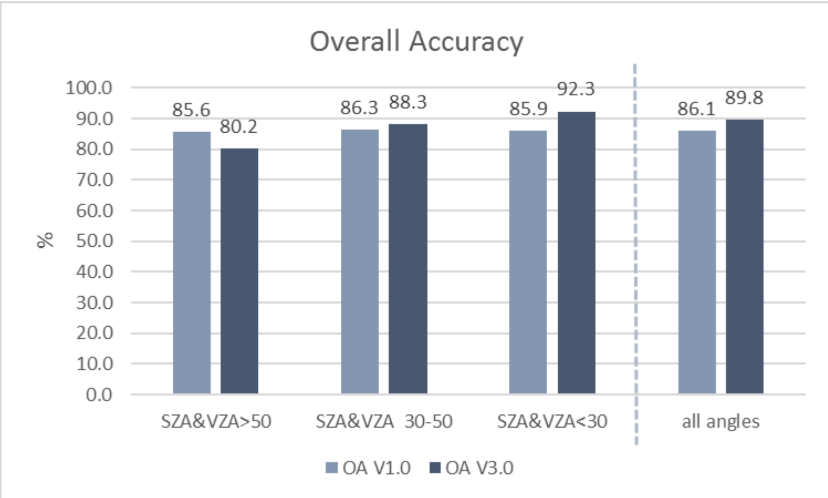


Figure 20: Overall Accuracy for Version 1.0 and Version 3.0 separated by different VZAs and SZAs.

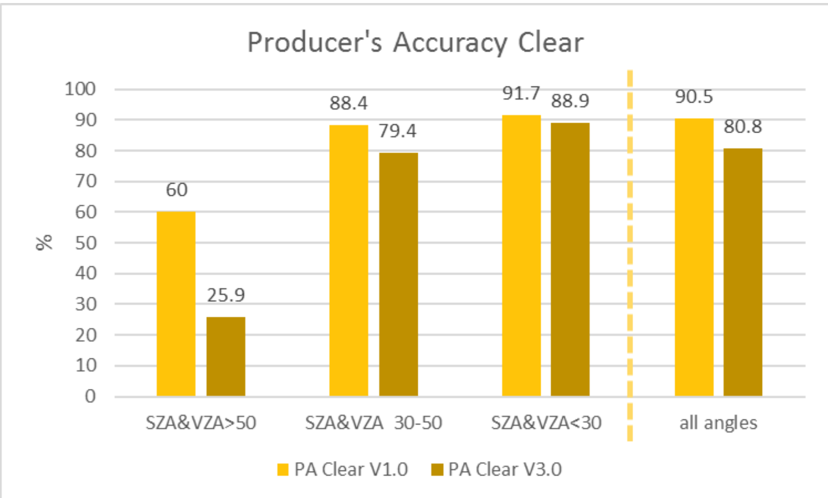


Figure 21: Producer's Accuracy Clear Pixels for Version 1.0 and Version 3.0 separated by different VZAs and SZAs.

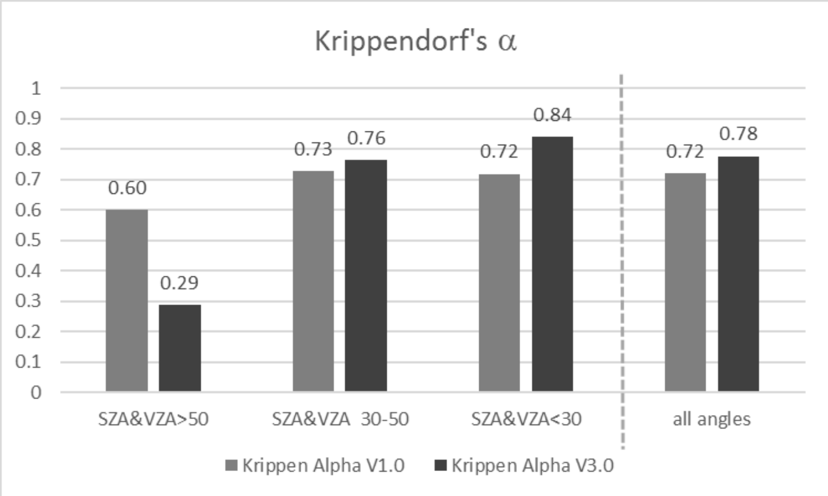


Figure 22: Krippendorf's α for Version 1.0 and Version 3.0 separated by different VZAs and SZAs.

4 Conclusion

It can be concluded that the Version 3.0 of the ProbaV Cloud Screening has improved overall compared to the current Version 1.0. This is especially the case for the detection of semi-transparent; more semi-transparent clouds are classified as CLOUD in Version 3.0 than in Version 1.0. Furthermore, the big issue in Version 1.0 which classified the bright clouds as SNOW/ICE has been improved with Version 3.0. This effect has not fully disappeared, but the areas have been significantly reduced. A third improvement is in the detection of turbid coastal waters as CLEAR in Version 3.0 and not as CLOUD, as it was the case in Version 1.0. Last but not least, the cloud edges are better captured within Version 3.0.

However, some issues remain or have been newly introduced. Clouds over water show artefacts at thin clouds (but not the cloud border) so that the CLOUD flag has many artificial holes over water. This issue should be solved in a next version of the cloud screening. Furthermore, coastal land pixels are often flagged as CLOUD, which might be caused by an inaccurate land/water flag and should be further investigate. The dependency of the viewing/sun geometry is higher in Version 3.0 than in Version 1.0 and should be further investigated in order to tune the thresholds accordingly, also with respect to turbid atmosphere which seems to have an effect here. Finally, in mountainous areas, valleys are often classified as SNOW/ICE, while the clear snow-ice covered pixels are well captured as SNOW/ICE.