M.Paperin, 21.01.2020

Investigation & Evaluation of "ProbaV-1km" cloud masking

The goal of this work is to qualitatively evaluate the properties, features and characteristics of a cloud- and snow mask as well as the correctness of cloud shadow determining. For this, the entire orbits and their fragments are examined visually. The (and fragments) are compared with each other, without and with the cloud mask. Sometimes the whole orbit is examined, sometimes just only its detail.

128 Satellite fragments (from four seasons) were examined and 226 color RGB images were produced. Each image exists also as individual file in "PNG" format.

For the long satellite fragments with many different cloud scenes, which are statistically representative for the cloud mask quality assessment (Subjective Cloud Mask Quality Rating - **SCMQR**), a subjective numerical rating (rating) from 0 to 10 is displayed, whereby "0" - the worst and "10" - the best grade is. Such fragments are marked in comments with symbol ⊙ .
For the investigation and assessment, 4 existing channels as well as RGB images were used. Two color palettes were applied

	red		green		blue	
RGB1	TOA_REFL_NIR	**843nm**	TOA_REFL_RED	**655.5nm**	TOA_REFL_BLUE	**462nm**
RGB2	TOA_REFL_SWIR	**1599nm**	TOA_REFL_NIR	**843nm**	TOA_REFL_BLUE	**462nm**

To distinguish cloud/ice masks from the surrounding picture of clouds and surface, the following colours are used

Mask colours

Clouds - **blue**, **pink**
Ice - **green**, **orange**
Shadow - **mustard-ocher**, **red**

The following irregular cases have been discovered. They are highlighted:
- Cloud-free pixels are marked as clouds.
- Cloudy pixels (except very thin ones) are marked as clear sky.
- Well done cloud/snow mask.
- Thin and very thin clouds are **not** marked as clouds.
- Oversaturated cloud pixels are incorrectly identified as ice.
- A clear sky land/sea snow/ice pixels are marked as cloudy.
- The dark, melting clear sky ice pixels are **not** marked as such.
- Sun glint was incorrectly recognized as cloudy.
- Cloud-free salt lake (as well as dry lakes/rivers) pixels are incorrectly marked as cloudy or icy.
- Sand storm, dust, aerosols are masked as cloudy.
- Spatially-mixed snow covered pixels are **not** recognized as such.
- Shadow sizes are defined incorrectly.

The impression that can be obtained after the check of approx. 130 satellite fragments is really positive. The quality is strongly dependent on the scene, but in most cases, where we are dealing with definitely opaque and undoubtedly semi-transparent clouds, or with a constant snow cover (that are approx. 85% of all examined cases), the masks work well indeed. Fog is marked as a cloud. The masks work rather moderately too satisfactorily in the cases of very thin (but still recognizable) semi-transparent or spatially mixed clouds, for semi-transparent clouds over ice and over desert. The presence of **<! SM_FLAGS.GOOD_BLUE>** -Flag changes the quality for both masks, but especially and more often for snow mask so that the rating drops in such situations. Most often, a cloud mask is incorrectly displayed instead of snow.
Dark, slightly melting sea ice is recognized as free water.
Spatially mixed snow covered or deeply snowed but well forested land surfaces are not marked with an ice mask.
Above cloud-free, dry or salted lakes and over the sun glint areas - the mask works rather unsatisfactory up to failing, far too often such pixels are wrongly marked as cloudy or snowy.
The quality of the cloud shadow mask has been examined as well. However, it appears irregularly and only marks a part of the shaded pixels. It is difficult to make an assessment here. Nevertheless, it will be discussed in more detail in this document.
Aerosols (mostly sand dust but also smoke) are sensibly recognized as clouds, although it can be seen that they are aerosols (such pixels are on purpose marked by me in PixBox as aerosols). Haze is moderate recognized.
As part of the "qualitative" grading, the SCMQR for the functioning of the entire cloud and ice masks is in all cases about ⊙ 8,5.

The **SCMQR** for different cloud types in the sense of [2]:

Media	*Surface*	*SCMQR*
Thick clouds #		9,0 - 10
Small cumulus clouds ^	over land	7,0 - 9,0
	over water	6,0 - 8,5
	over water (at sun glint)	5,5 - 8,5
Semi-transparent clouds „usual“	over land, water	8,0 - 9,0
Sem-itransparent clouds „very thin“	over land, water	2,0 - 5,0

The SCMQR for different surfaces in the sense of [2]:

Media	*Surface*	*SCMQR*
Clouds over land (all cloud types)	over „usual“ land	7,5 - 8,5
Clouds	over desert	6,0 - 8,0
Clouds	over salt lake	4,0 - 7,0
Clouds	over city	7,0 - 8,5
Clouds	over ice/snow	7,5 - 8,5
Clouds over water (all cloud types)	over water	8,0 - 9,0
Clouds	over Inland water	7,5 - 8,5
Clouds	over floating ice	6,5 - 8,5
Clouds	over sun glint	7,0 - 8,5

The SCMQR for different surfaces in the sense of [1]:

Media	*Surface*	*SCMQR*
Cloud free over land	over „usual“ land	9,5 - 10
	over desert	8,0 - 9,0
	over salt lake	2,0 - 6,0
	over city	6,0 - 8,5
	over ice/snow	2,5 - 7,5
	over spatially mixed ice/snow	2,0 - 6,5
Cloud free over water	over water	9,0 - 10
	over Inland water	8,5 - 9,5
	over floating ice	3,5 - 7,5
	over sun glint	2,0 - 6,5

The **SCMQR** for the "Snow/Ice mask quality rating" in the sense "if it is visible, it is marked ":

Media	*Surface*	*SCMQR*
Inland ice/snow (cloud free)	Thick snow layer	9,5 - 10
	Spatially mixed, or slightly sprinkled	2,0 - 6,5
	Inland thick ice	8,0 - 9,5
	Inland thin ice	2,0 - 5,0
Floating ice (cloud free)	Very close thick pack ice	8,0 - 9,0
	Dark melting floating ice	1,5 - 4,0
	Spatially mixed, or slightly sprinkled	4,0 - 7,0

However not all saturated areas, at the really very bright pixels - ice instead of cloud; therefore from 9,0.

^ So-called "spatially mixed clouds" - clouds that are smaller than one pixel size (in our case smaller than 1km^2)

The detection of shadows causes a lot of questions. Only a small part of shadow pixels are marked on the same satellite fragment although there are and are definitely recognizable. Large parts of the fragment remain without shadow marking. The shadows themselves are mostly narrow and stick to the side of the clouds facing away from the sun. This says something about the algorithm with which shadows information was obtained: the recognized clouds with a certain height are used to calculate the shadows, not recognize them. It means that when determining the shadow size, only the height of the clouds is taken into account. I suppose this height is not found or calculated from the satellite data, but some standard height, presumably about 3 km, was taken. The darkening of the surface due to its shading is not taken into account at all. I find the current shadow mask unsatisfactory and unsuitable.

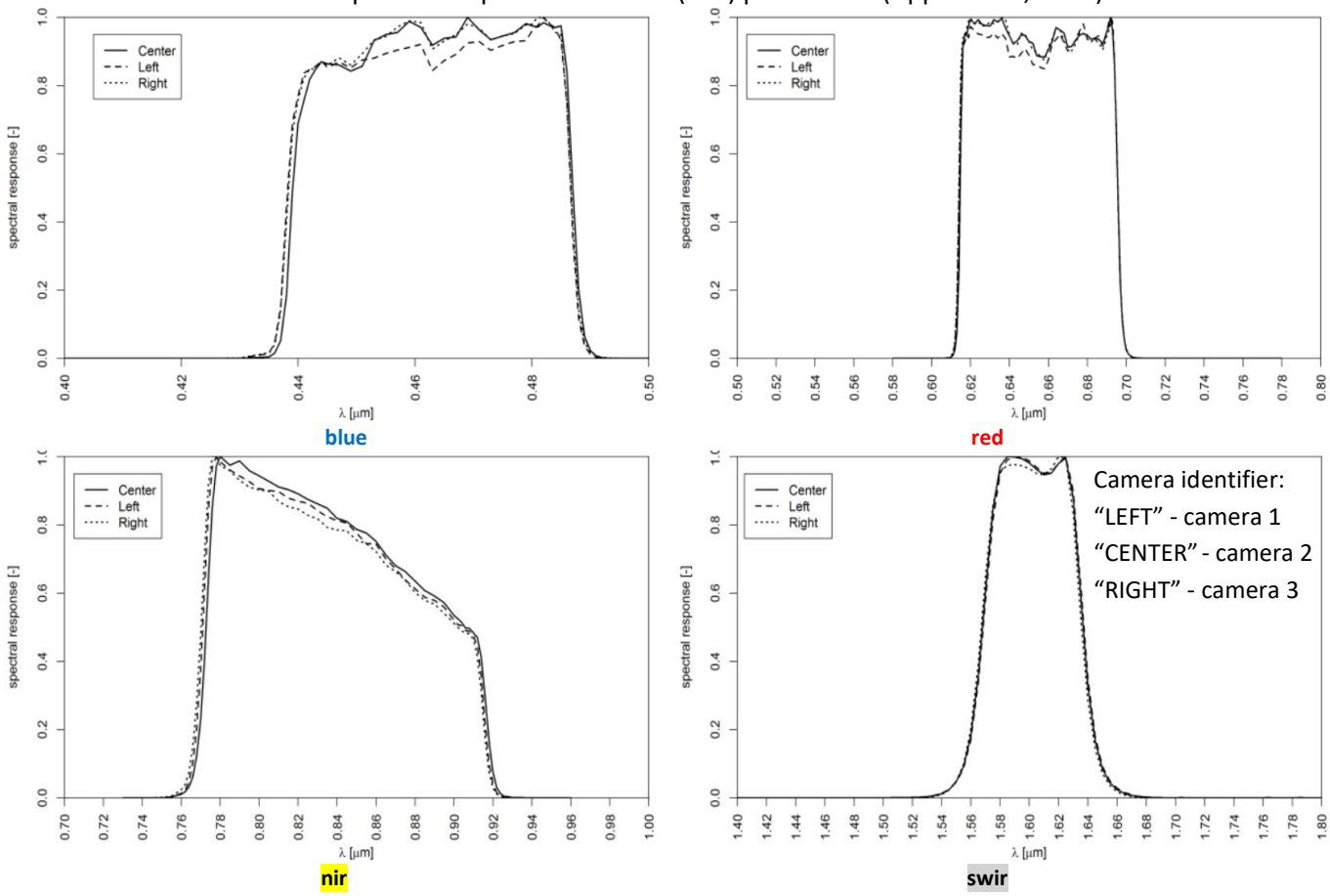
I got the impression that the cloud masks (maybe the ice mask as well) for the data taken from the three cameras on board the satellite are slightly different one from another, whereby number 3 is not the best. This is just a feeling, because there is no synchronous data from different cameras. But the information below can confirm my suspicions.

Notes about Proba-V, 2a

http://proba-v.vgt.vito.be/sites/proba-v.vgt.vito.be/files/products_user_manual.pdf

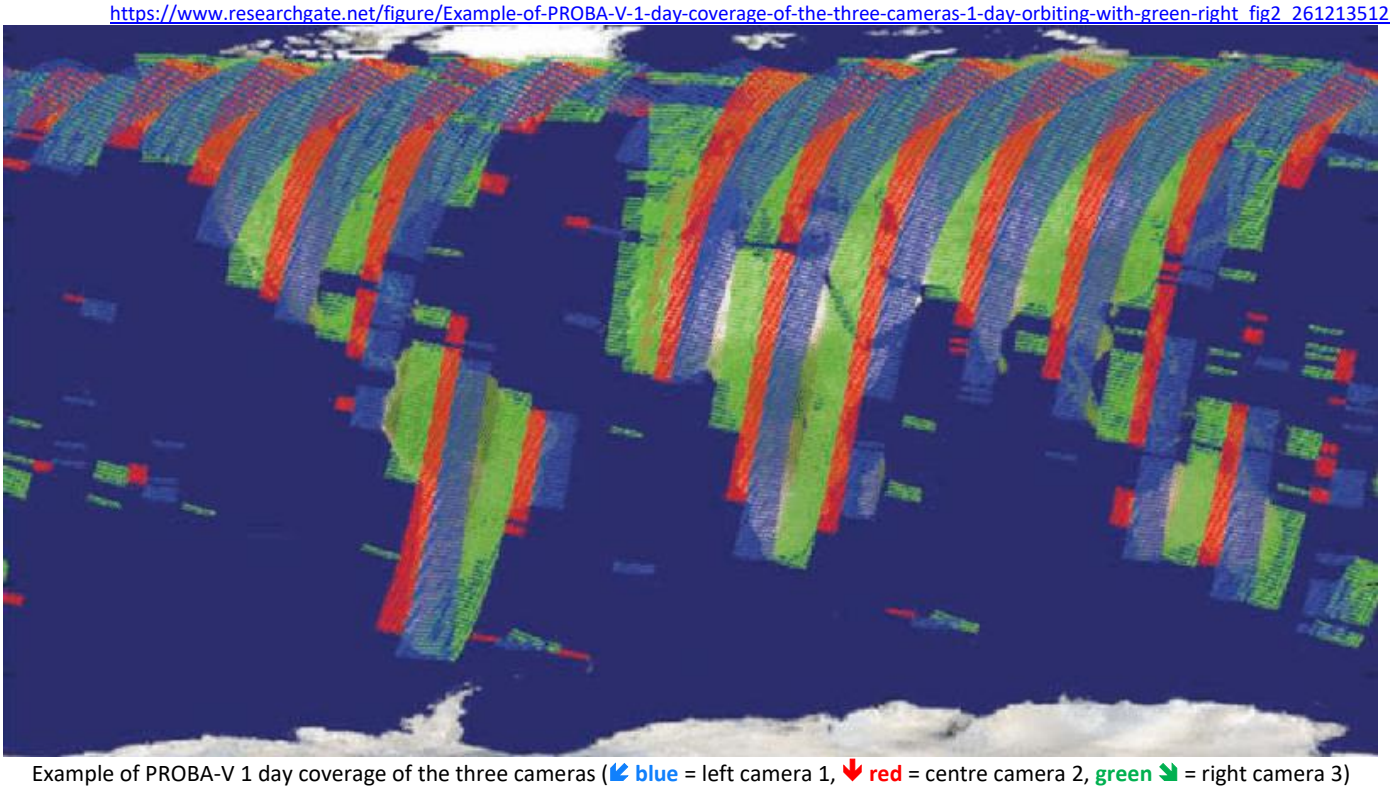
P. 97, Appendix E2: Detailed Level 2A Product file description

PROBA-V Spectral Response Functions (SRF) per camera (Appendix A, P. 72)



	Wavelengths	Resolution	Use
Blue	438-486nm	100/600m	Atmospheric corrections
Red	615-696nm	100/600m	Peak of chlorophyll absorption
NIR	772-914nm	100/600m	Maximum vegetation reflectance
SWIR	1564-1634nm	200/700m	Canopy structure and water content

https://www.researchgate.net/figure/Example-of-PROBA-V-1-day-coverage-of-the-three-cameras-1-day-orbiting-with-green-right_fig2_261213512



Example of PROBA-V 1 day coverage of the three cameras (**blue** = left camera 1, **red** = centre camera 2, **green** = right camera 3)

Images to evaluation the quality of cloud, ice and shadow masks

Content

1. PROBAV_L2A_20140321_012314_1_1KM_V103 (Pacific Ocean in the east of Kamchatka Peninsula)
- A well done cloud-, land snow, floating ice mask.

2. The same Fragment.
- Some clear sky land ice pixels are wrongly marked as cloudy.

3. The same Fragment.
- Some clear sky land ice pixels are wrongly marked as cloudy.

4. PROBAV_L2A_20140321_000131_1_1KM_V103 (New Caledonia, Vanuatu, Pacific Ocean)
- A well done cloud mask.

5. The same Fragment.
- Sun glint pixels are wrong recognized as cloudy.

6. PROBAV_L2A_20140321_000656_2_1KM_V103 (East Australia, Pacific Ocean)
- Oversaturated cloud pixels are incorrectly identified as ice.

7. PROBAV_L2A_20140321_011849_3_1KM_V103 (Sakhalin island, Japan Sea)
- - Very thin clouds are marked as clouds.

8. PROBAV_L2A_20140321_044547_1_1KM_V103 (Top: Siberia, lake Baikal; Bottom: Indian Ocean, Java Island)
- A well done cloud mask.
- Some sun glint pixels are wrong recognized as cloudy.

9. PROBAV_L2A_20140321_030005_3_1KM_V103 (Top: East Siberia; Bottom: Indochina)
- A well done cloud-, land snow, floating ice mask.

10. The same Fragment.
- Mist/haze well recognized!
- Shadows are only partially shown.

11. The same Fragment (Indian cities).
- Clouds above the cities are shown instead of clear sky. Non-existent clouds create shadows that do not exist really.

12. PROBAV_L2A_20140321_031830_2_1KM_V103 (Pacific Ocean)
- Clouds are well recognized, but too coarse: many cloud-free pixels were marked as clouds.

13. The same Fragment.
- Very many incorrect recognized (part oversaturated) sun glint pixels: clouds instead of free.
- And there are shadows from clouds that do not exist.

14. PROBAV_L2A_20140321_032645_1_1KM_V103 (West Australia)
- Clouds have been well recognized. Cloud shadows are reasonable. It should be although noted that the shadows stick to the associated clouds, which is not always correct.

15. PROBAV_L2A_20140321_044105_3_1KM_V103 (Desert Takla Makan)
- Part of the desert, rather doubtfully, was marked as cloudy. Perhaps is understood as sand dust?

16. PROBAV_L2A_20140321_062221_3_1KM_V103 (Southeast of Arabian Peninsula)

Part of the desert was wrong marked as cloudy in my opinion.

17. PROBAV_L2A_20140321_064750_3_1KM_V103 (East Coast of Madagascar)

Not all (although very thin) clouds are marked as such.

18. The same Fragment.

Shadow sizes are defined incorrectly. Perhaps the algorithm uses only one standard height of the top cloud surface (ca. 3km). On the right fragment side, shadows are not identified at all, although they are there.

19. PROBAV_L2A_20140321_080358_2_1KM_V103 (Northwest of Kazakhstan)

The steppe is partly covered with snow (spatially-mixed). Not identified. Otherwise the clouds and snow have been well separated. Shadows - OK, because the clouds are not high.

20. PROBAV_L2A_20140321_080358_2_1KM_V103 (East of Alps, North of Adriatic Sea)

Thin clouds over the mountains are well recognized.

21. PROBAV_L2A_20140321_112632_2_1KM_V103 (Atlantic Ocean, West Africa, Liberia Coast)

Sun glint was incorrectly recognized as clouds. Shadow size is too narrow due to incorrect estimation of the cloud height.

22. The same Fragment.

Clearly visible semi-transparent clouds (over Western Sahara) were not masked. Gross mistake.

23. PROBAV_L2A_20140321_113854_3_1KM_V103 (Atlantic Sea, West Africa, Mauretania Coast)

Thin clouds over the sea are recognized not well enough.

Light salt lake pixels (on the right) was masked as a cloud.

24. PROBAV_L2A_20140321_132915_3_1KM_V103 (East of South America, Brazil)

A well done cloud mask.

25. PROBAV_L2A_20140321_133010_1_1KM_V103 (South America, Brazil, State of Bahia)

Cloud shadows are partly too skimpy due to incorrect cloud height estimation.

26. PROBAV_L2A_20140321_144841_3_1KM_V103 (West Greenland, Davis Strait)

A lot of clear sky land ice and sea ice pixels are wrongly marked as cloudy.

27. The same Fragment.

Not all of clear sky ice pixels are marked, melting ice pixels are not.

28. PROBAV_L2A_20140321_144902_2_1KM_V103 (East Greenland)

A lot of land ice and sea ice pixels are wrongly marked as cloudy.
The "not good blue" flag probably affects the making the right decision.

29. PROBAV_L2A_20140321_150637_1_1KM_V103 (Bolivia, Salar de Uyuni)

Cloud-free salt lake pixels are incorrectly marked as cloudy or icy.

30. PROBAV_L2A_20140321_162957_3_1KM_V103 (Hudson Bay)

A lot of clear sky land ice and sea ice pixels are wrongly marked as cloudy.

31. PROBAV_L2A_20140321_163018_2_1KM_V103 (In the Great Lakes area)

Some spatially mixed pixels are not recognized.

A lot of clear sky sea darks, melting ice pixels are not recognized.

32. The same Fragment (America Midwest)

Many semi-transparent clouds are not recognized.

33. PROBAV_L2A_20140321_231600_2_1KM_V103 (Bering Sea, Chukchi Sea)

- A good recognition of clear sky land ice and sea ice as well as separation of clouds.

It seems to me that camera "2" works a little better in this sense. Although I cannot prove it.

34. PROBAV_L2A_20140621_055928_3_1KM_V103 (Uzbekistan, Tadzhikistan) + The same area zoomed.

- Here I am not sure about the correct application of masks.

35. The same Fragment (North India, Sun glint on land)

- Completely wrong masking of sun glint area.

36. PROBAV_L2A_20140621_074052_3_1KM_V103 (Caspian Sea)

- The aerosol is partially mistaken for cloud cover.

37. PROBAV_L2A_20140621_060411_1_1KM_V103 (In the top - West Siberia, Kazakhstan, in the bottom - India)

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38. PROBAV_L2A_20140621_074105_2_1KM_V103 (Gulf of Ob)

- Not all floating ice pixels are recognized.

39. The same Fragment (Persian Gulf)

- Wrong masking of sun glint area.

40. The same Fragment (Caspian Sea, Kara-Bogaz-Gol Gulf)

- Wrong masking of sun glint area.

41. PROBAV_L2A_20140621_074527_1_1KM_V103 (West of Indian Ocean)

- Semi-transparent clouds are not masked.

42. PROBAV_L2A_20140621_092203_3_1KM_V103 (Sahara)

- In my opinion this is not cloud, but sand dust, aerosol.

43. The same Fragment (Mediterranean, Crete)

- Wrong masking of sun glint area.

44. PROBAV_L2A_20140621_110705_3_1KM_V103 (Spain)

- Well done cloud mask.

45. PROBAV_L2A_20140621_110758_1_1KM_V103 (Alps)

- Everything is fine here as well.

46. PROBAV_L2A_20140621_144544_1_1KM_V103 (Uruguay)

- Not all semi-transparent clouds are masked as such.

47. PROBAV_L2A_20140621_160704_3_1KM_V103 (Canada, peninsula D' Ungava, in the North of Akulivik)

- Cloud shadows

48. PROBAV_L2A_20140621_160704_3_1KM_V103 (Hudson Strait)

- Wrong masked or not recognized floating ice pixels

49. PROBAV_L2A_20140621_192935_3_1KM_V103 (Canadian arctic archipelago)

- Pretty good ice and cloud mask, except for dark sea ice

50. PROBAV_L2A_20140621_175302_1_1KM_V103 (South America)

- Cloud shadows

51. PROBAV_L2A_20140621_035355_3_1KM_V103 (Northeast of Indian Ocean, Andaman Islands)

- The well done cloud mask

52. PROBAV_L2A_20140621_053508_3_1KM_V103 (West of Takla Makan Desert)

- Aerosol covered desert (sandstorm, dust) marked as cloudy. Is that correct?

53. PROBAV_L2A_20140621_053530_2_1KM_V103 (Takla Makan Desert)

- A dried riverbed is wrong marked as cloudy.
- Some cloud pixels are labelled as snow covered.

54. PROBAV_L2A_20140621_071646_2_1KM_V103 (From Ural Mountains to Horn of Africa)

55. The same Fragment (Karakum Desert)

- Cloud shadows (a bit too narrow)

56. PROBAV_L2A_20140621_074055_2_1KM_V103 (Strait of Mozambique)

- Some very thin and spatially mixed clouds are not recognized

57. PROBAV_L2A_20140621_085802_2_1KM_V103 (Tuz Gölü, salt, partially dry lake)

- The bright surface of salt lake is wrong marked as snow / ice covered

58. PROBAV_L2A_20140621_085937_3_1KM_V103 (Ionian Sea, Greece)

- It is a sand storm over Ionian Sea. It is labelled as cloudy. Is it correct?

59. PROBAV_L2A_20140621_104339_1_1KM_V103 (Ionian Sea, Italy)

- The same situation as in the Nr. 57

60. The same Fragment (Sahara)

- Aerosol pixel are recognized as cloudy, is it correct?

61. PROBAV_L2A_20140621_123717_2_1KM_V103 (East Atlantic, Canarias)

- A lot of sun glint pixels (the bottom right corner of the image) are wrong labelled as cloudy (and sometimes even as ice)

62. PROBAV_L2A_20140621_154245_3_1KM_V103 (Baffin Island)

- A lot of clear sky snow/ice covered pixels are erroneous masked as cloudy pixels.

63. PROBAV_L2A_20140621_172401_3_1KM_V103 (South America)

- Clouds and shadow - well hit.

64. PROBAV_L2A_20140621_172401_3_1KM_V103 (West Australia)

- Salt, in places dry lakes are wrong labelled as cloudy or icy.

65. PROBAV_L2A_20140621_004943_2_1KM_V103 (Goodenogh Bay, Papua)

- A lot of sun glint pixels are wrong as cloudy or icy (if particularly bright) recognized.

66. PROBAV_L2A_20140621_021446_3_1KM_V103 (Southwest Siberia, North China, Korea)

- A well done mask

67. PROBAV_L2A_20140621_022940_1_1KM_V103 (Timor Sea)

- A lot of sun glint pixels are wrong as cloudy or icy (if particularly bright) recognized.

68. PROBAV_L2A_20140621_035559_1_1KM_V103 (China between Henan and Guangdong)

- Fog, haze have been well captured. Very thin fog remained undetected. The cloud mask is exceptionally **black.**

69. PROBAV_L2A_20140621_035603_3_1KM_V103 (Assam, Myanmar)

- Shadows are not full enough

70. PROBAV_L2A_20140621_053714_1_1KM_V103 (Nepal)

- Well distinguished snow from fog and clouds.

71. PROBAV_L2A_20140621_053718_3_1KM_V103 (North India)

- It was managed to prevent from being irritated by very dark shadows above the cloud layer. Really very good cloud recognition.

72. The same Fragment (zoomed)

- Cloud shadows are recognized not very successfully

73. PROBAV_L2A_20140621_071829_1_1KM_V103 (Arabian Sea)

- Semi-transparent clouds are not labelled completely

74. PROBAV_L2A_20140621_085947_2_1KM_V103 (Egypt)

- A lot of semi-transparent clouds are not marked

75. PROBAV_L2A_20140621_085949_3_1KM_V103 (Sahara)

- Sand storm is erroneously misunderstood as cloud layer

76. PROBAV_L2A_20140621_104101_1_1KM_V103 (West Sahara)

- Cloud shadows are not labelled completely.
- Semi-transparent clouds are labelled sensible enough.
- This is a very rare case when the algorithm spatially separated the clouds and their shadows, so that they do not touch.

77. The same Fragment

- A large territory covered with the very thin haze remained unrecognized

78. PROBAV_L2A_20140621_104105_3_1KM_V103 (Caucasus)

- An interesting image. In the north of mountains are clouds, in the south - fog. All is well masked.
- Obviously, the fog was recognized as clouds, the fog has no shadow and there is no such thing in the picture either.

79. PROBAV_L2A_20140621_154448_2_1KM_V103 (new Brunswick)

- Spatially mixed snow (in this case mostly snow covered coniferous forests) is almost never marked. This is a big flaw.

80. PROBAV_L2A_20140621_172608_3_1KM_V103 (Canada)

- Here, too, irregularly covered with snow areas (somewhat darker than a closed blanket of snow - the earth peeps out) are incorrectly recognized as a cloud.

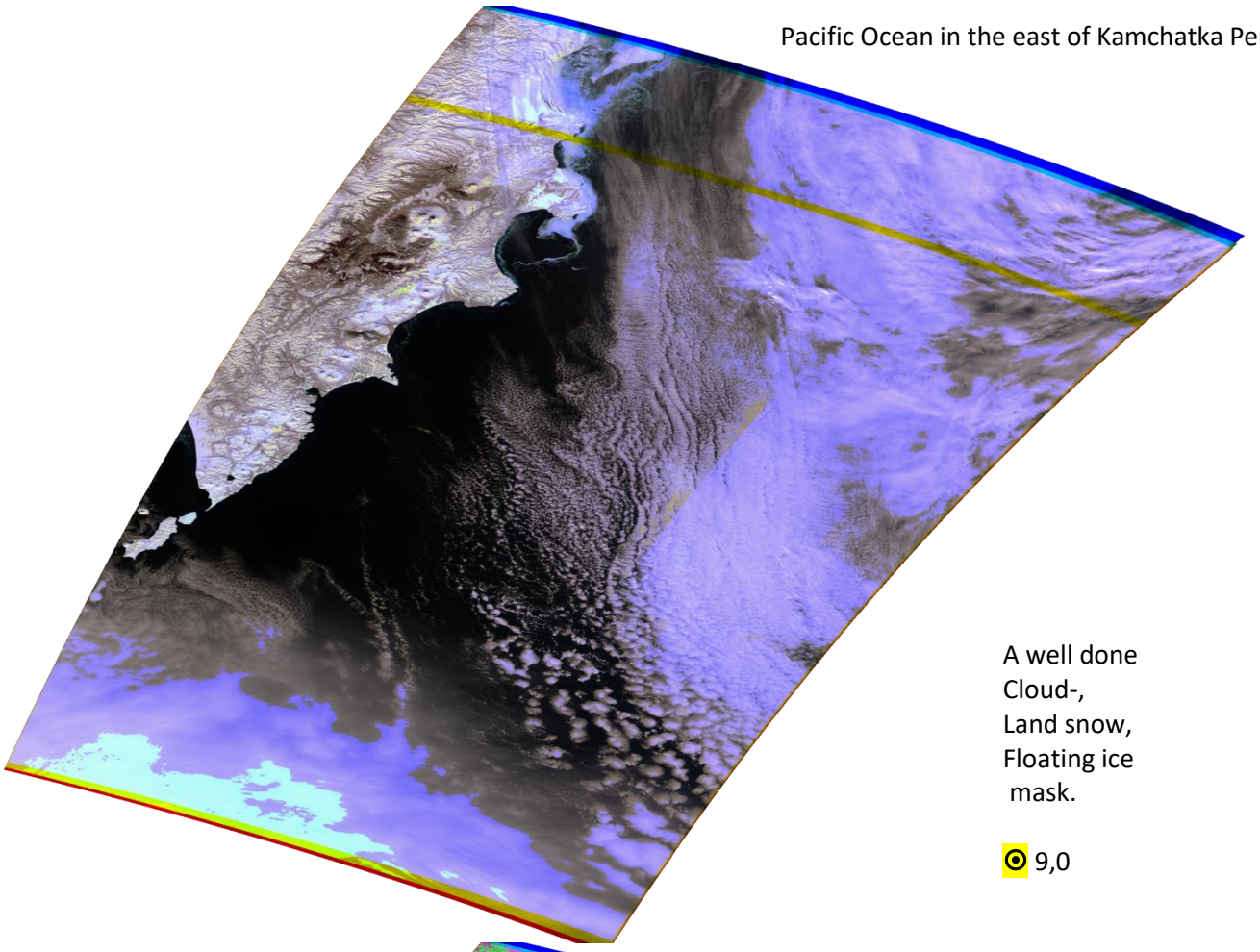
81. PROBAV_L2A_20140621_225542_1_1KM_V103 (New Zealand, Tongariro Volcano)

- Clouds and snow are well marked. It is strange that a shadow has been registered around a snow-covered volcano. When analysing the images of this satellite, I never noticed that the dark areas are just automatically recognized like shadows.

Images

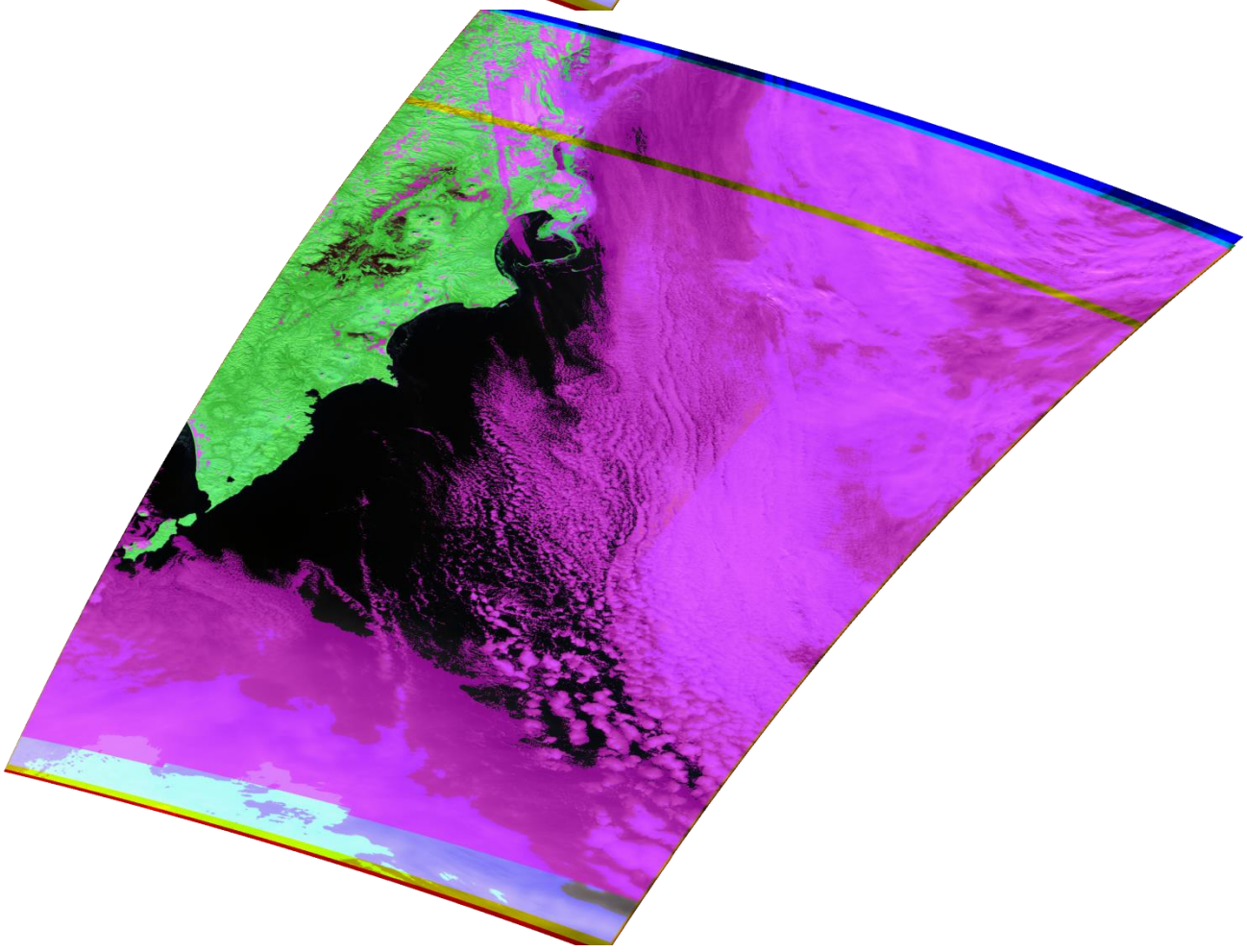
1. PROBAV_L2A_20140321_012314_1_1KM_V103

Pacific Ocean in the east of Kamchatka Peninsula

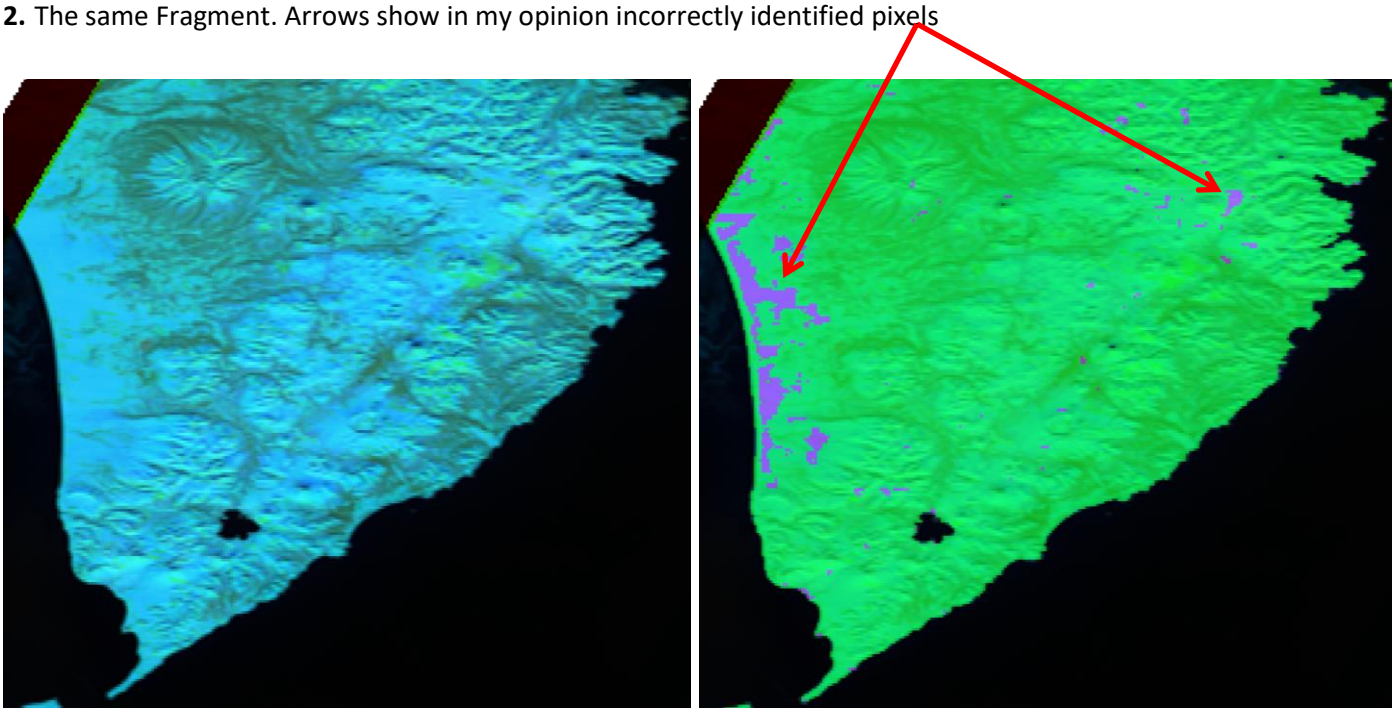


A well done
Cloud-,
Land snow,
Floating ice
mask.

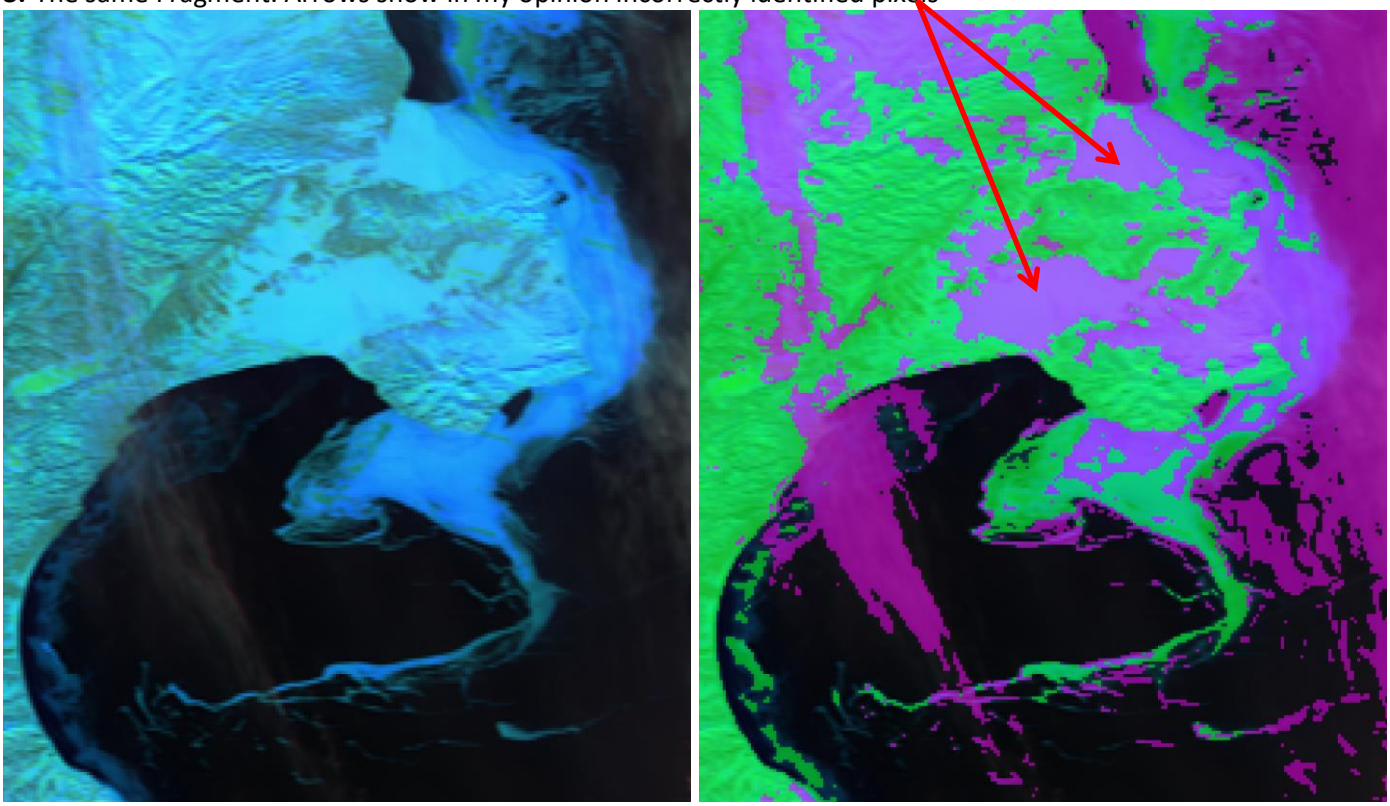
⊙ 9,0



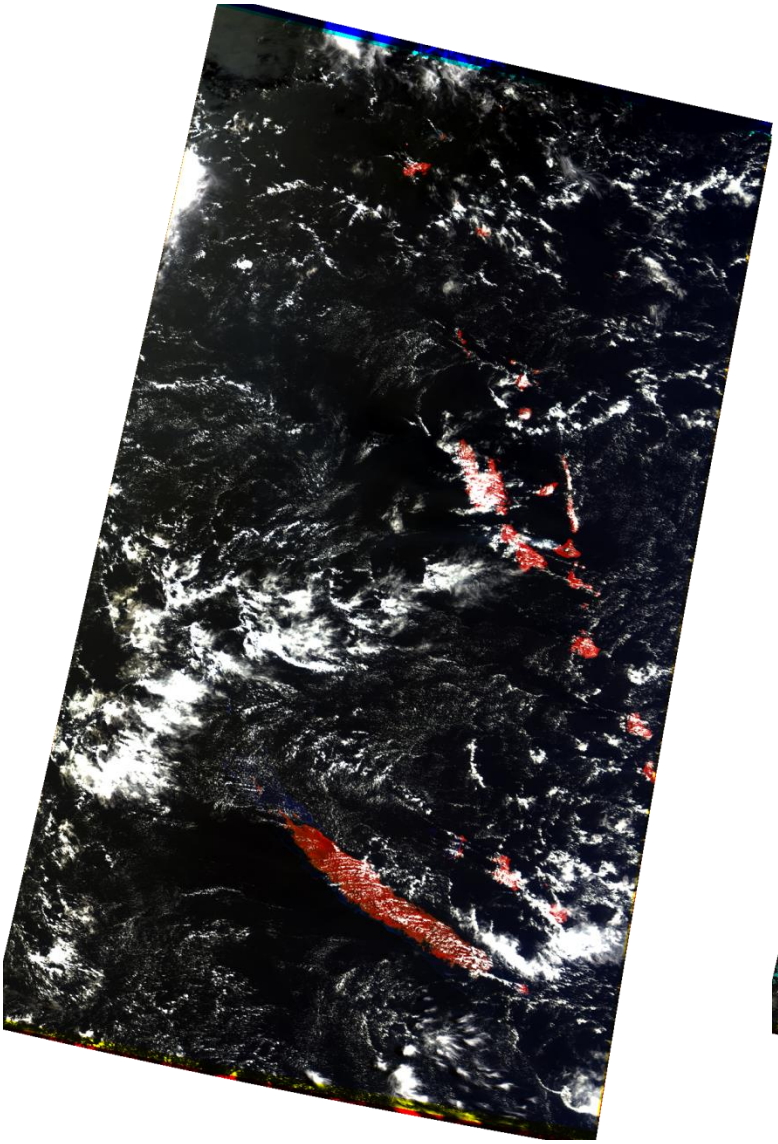
2. The same Fragment. Arrows show in my opinion incorrectly identified pixels

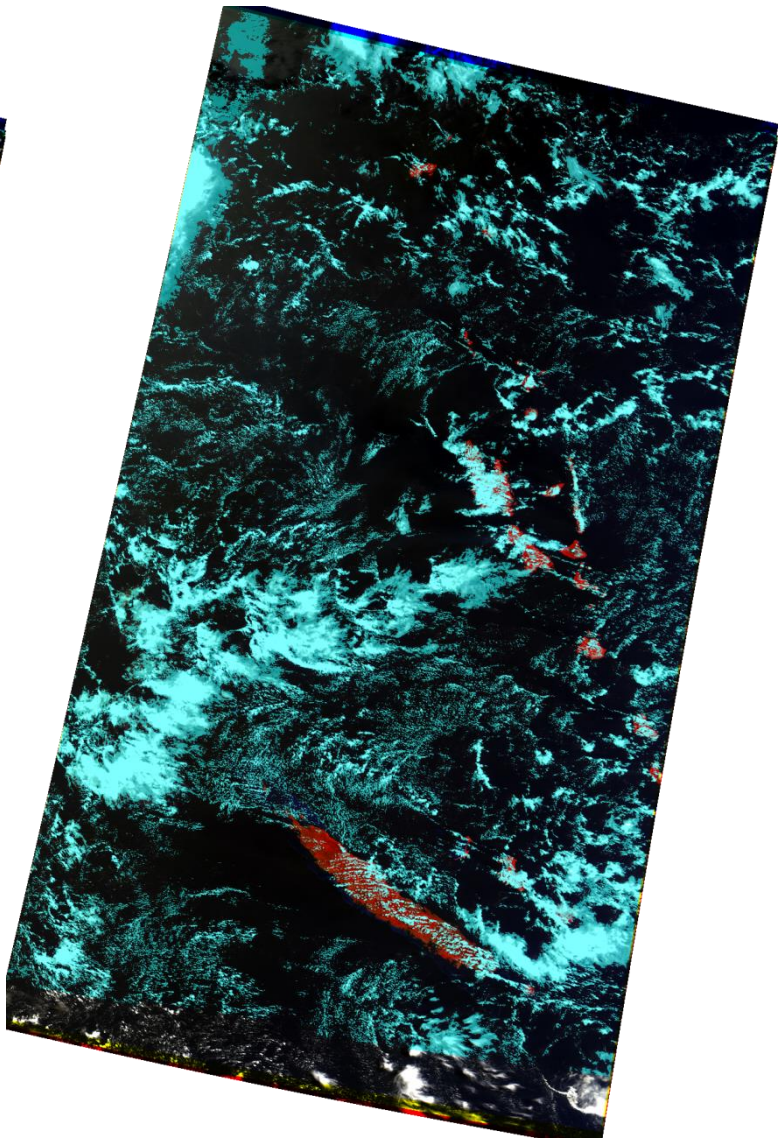


3. The same Fragment. Arrows show in my opinion incorrectly identified pixels

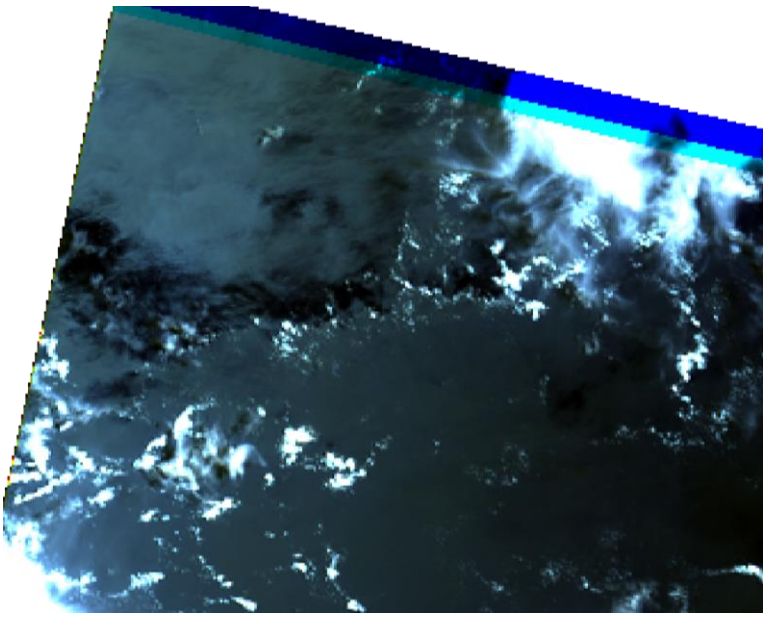


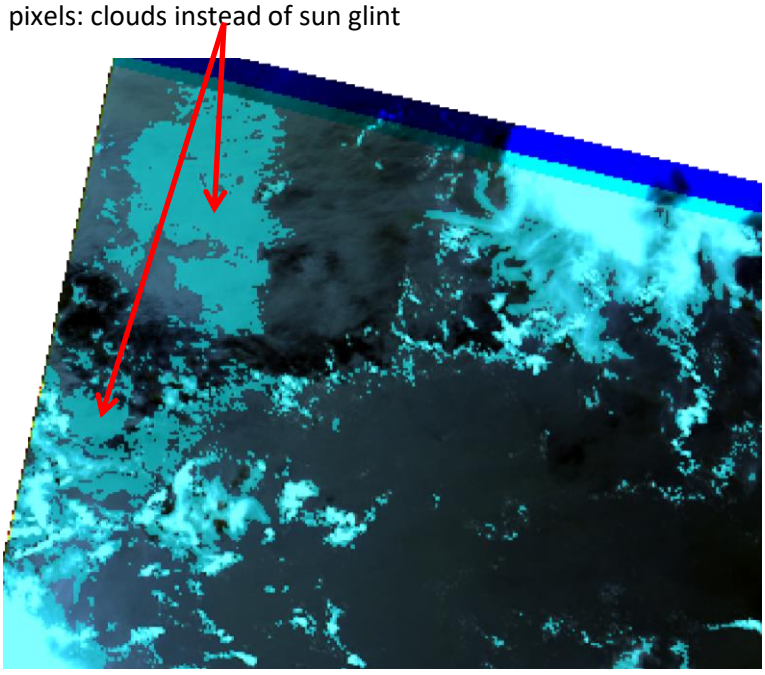
4. PROBAV_L2A_20140321_000131_1_1KM_V103 (New Caledonia, Vanuatu, Pacific Ocean ⊙ 9,0)



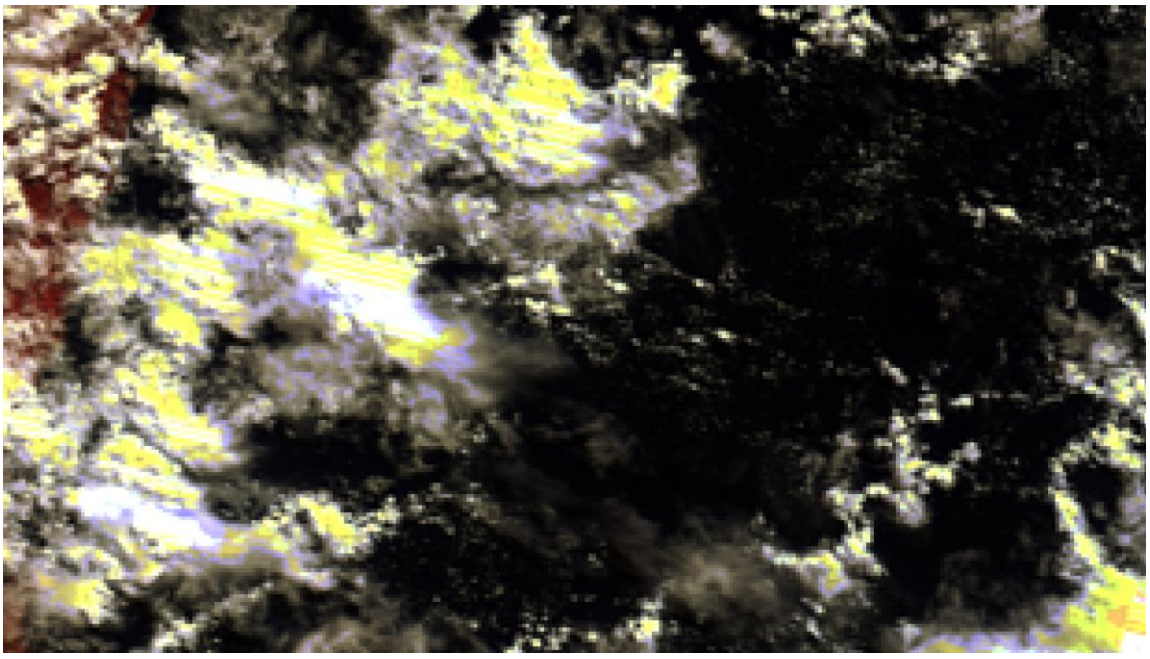


5. The same Fragment. Arrows show incorrectly identified pixels: clouds instead of sun glint

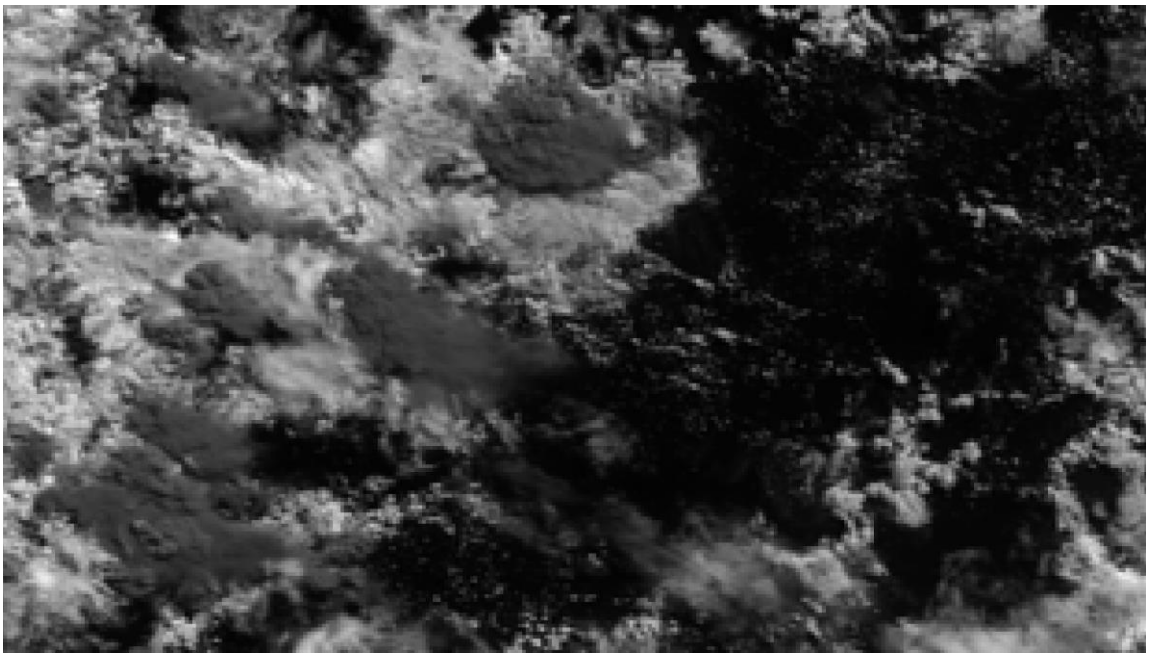




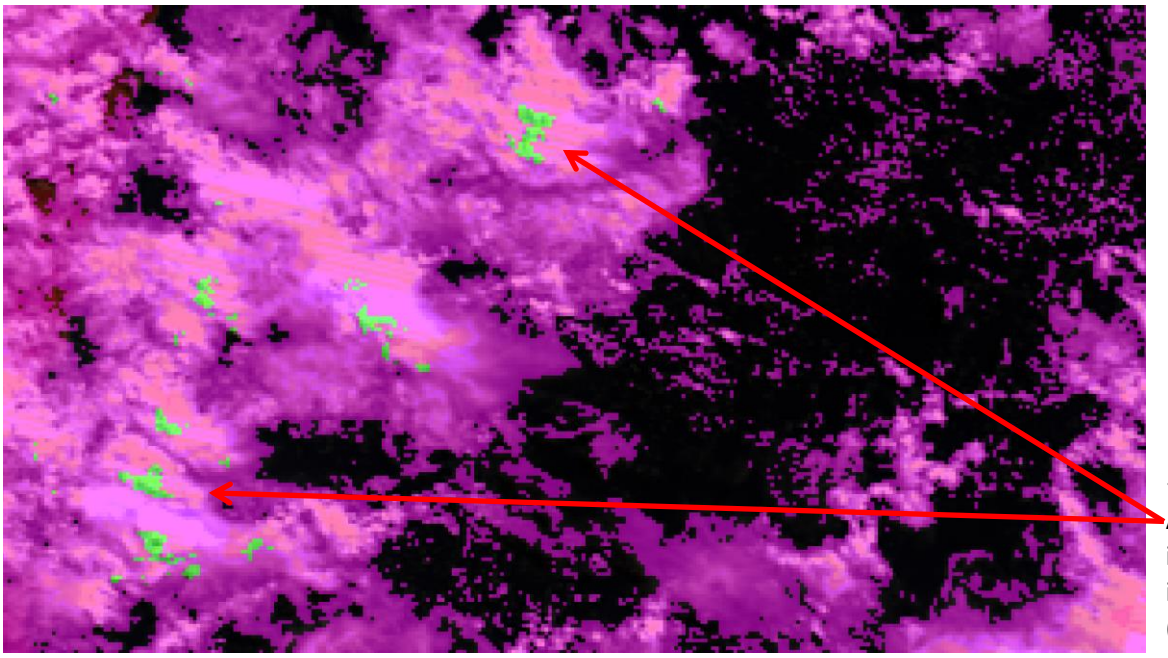
6. PROBAV_L2A_20140321_000656_2_1KM_V103 (East Australia, Pacific Ocean ⊙ 7,0)



→ RGB 1

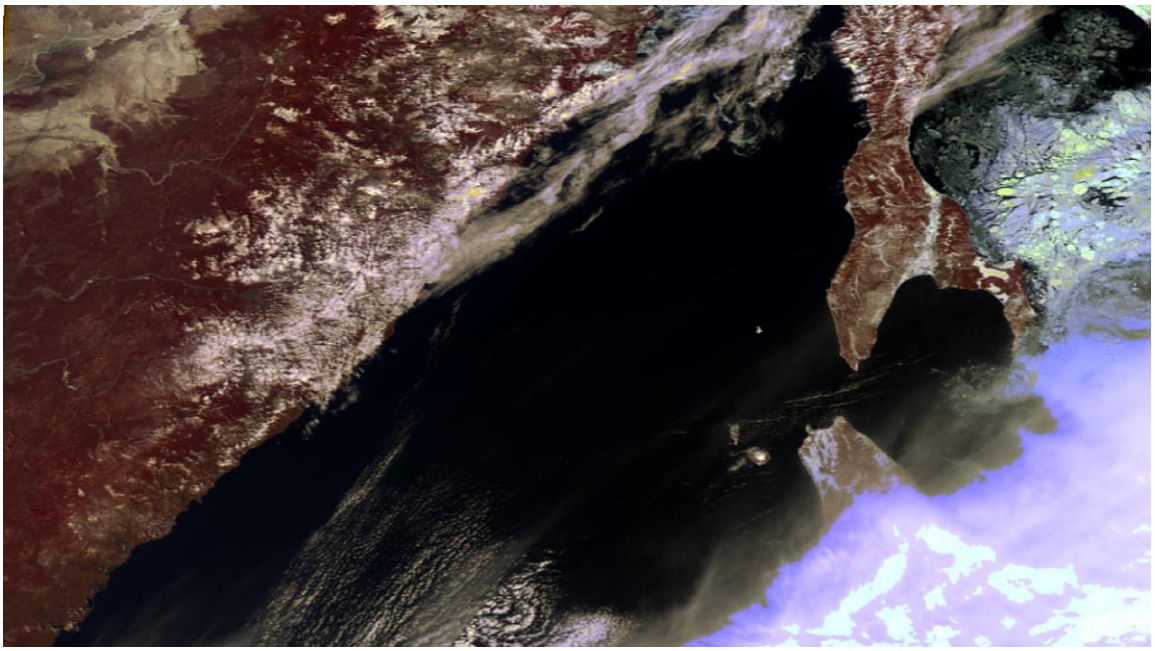


→ SWIR

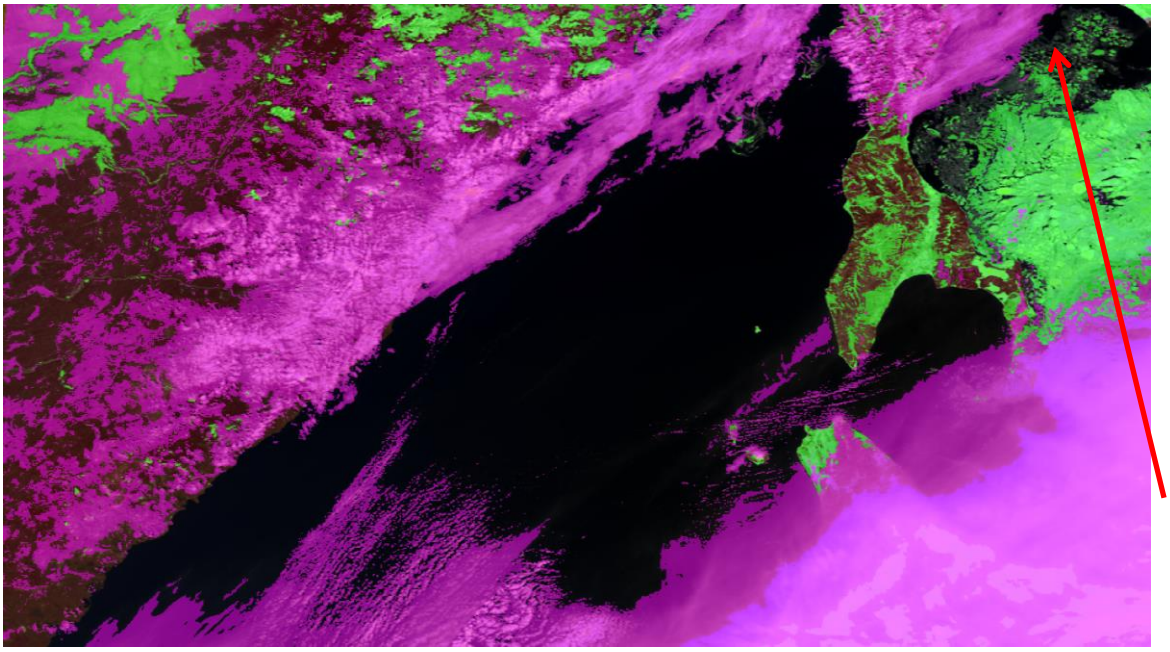


→ Cloudmask
Arrows show incorrectly identified pixels:
ice instead of clouds
(*pixel are oversaturated*)

7. PROBAV_L2A_20140321_011849_3_1KM_V103 (Sakhalin island, Japan Sea ⊙ 8,5)

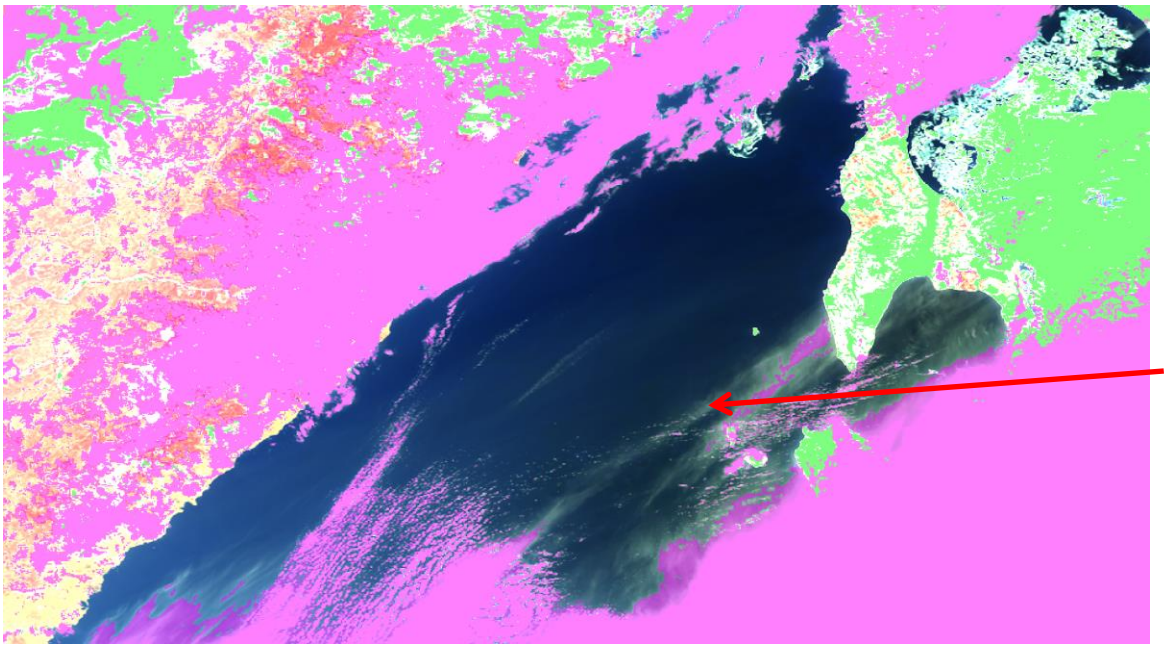


→ RGB 1



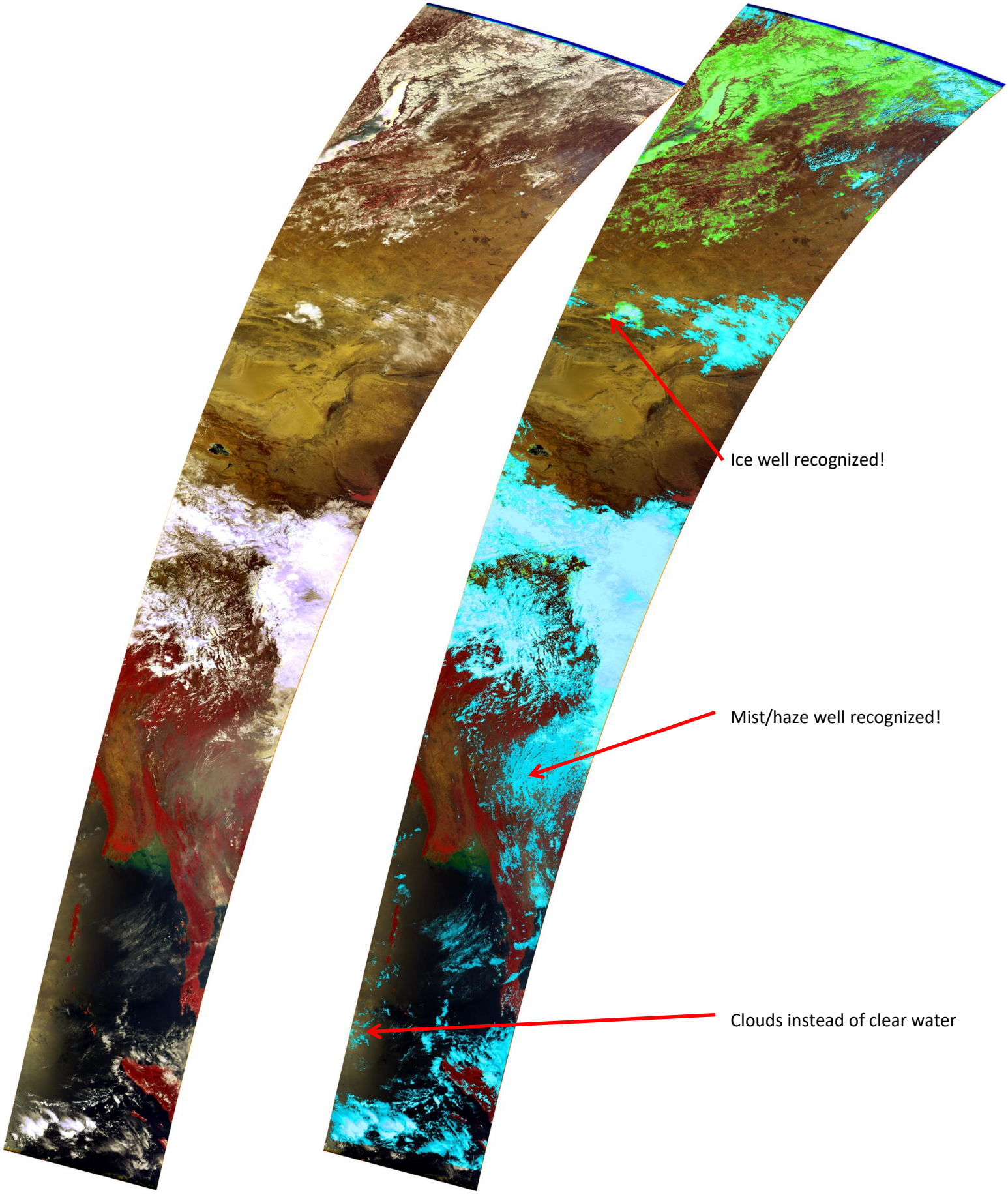
→ Cloudmask

Arrows show incorrectly identified pixels:
clear water instead of floating ice

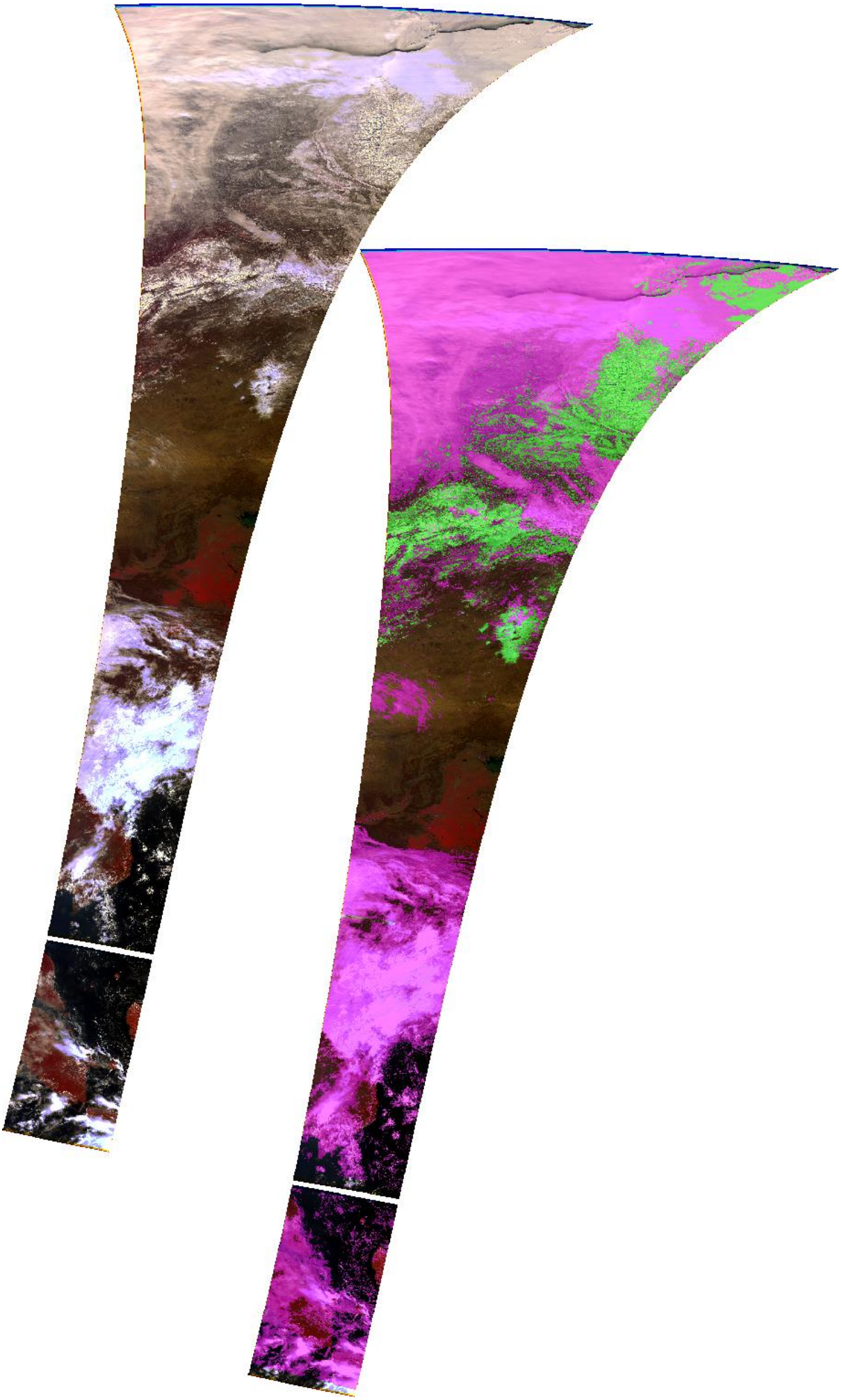


Arrows show incorrectly identified pixels:
clear water instead of semi-transparent clouds (very thin)

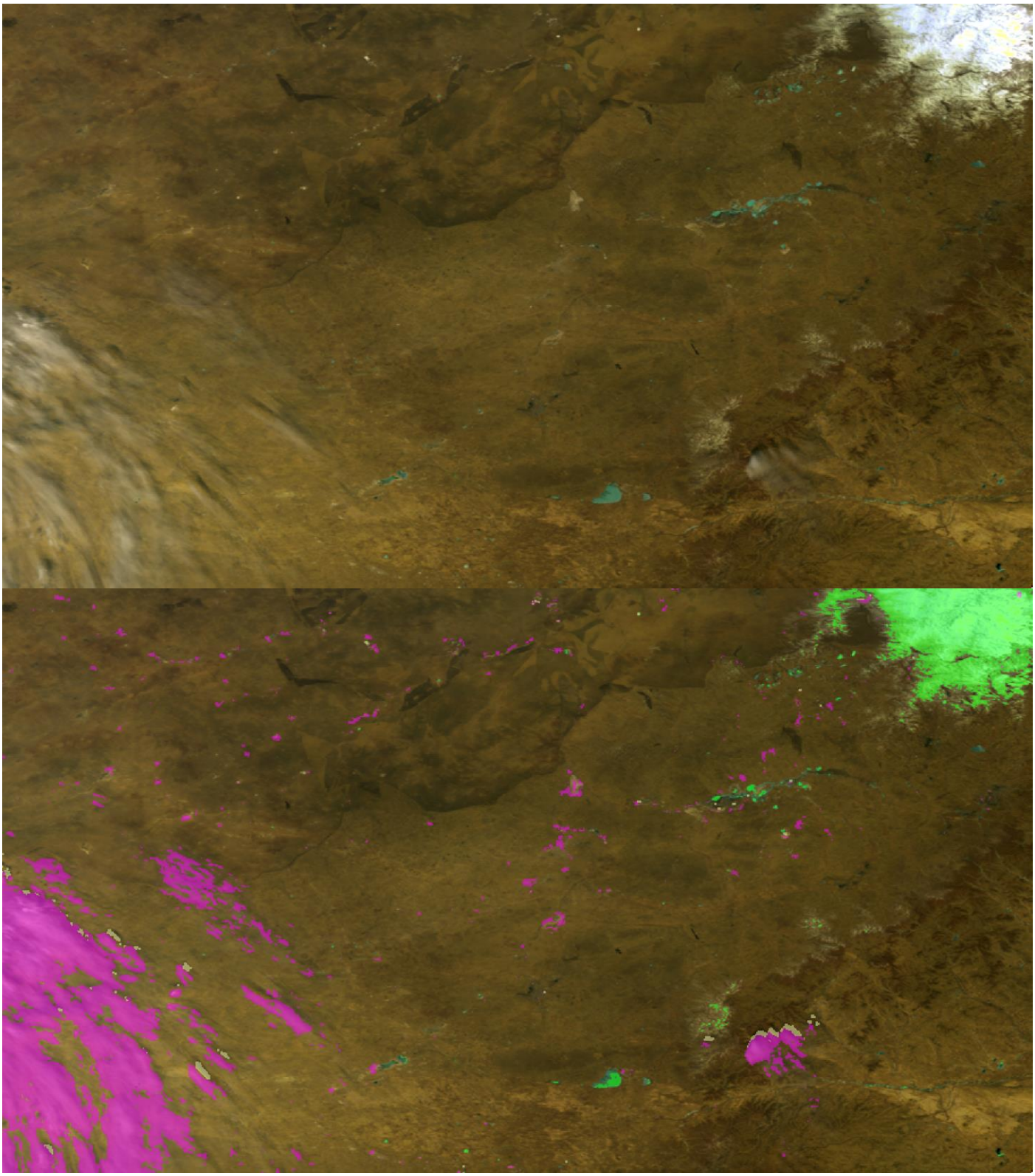
8. PROBAV_L2A_20140321_044547_1_1KM_V103 (Top: Siberia, lake Baikal
Bottom: Indian Ocean, Java Island ⊙ 8,5)



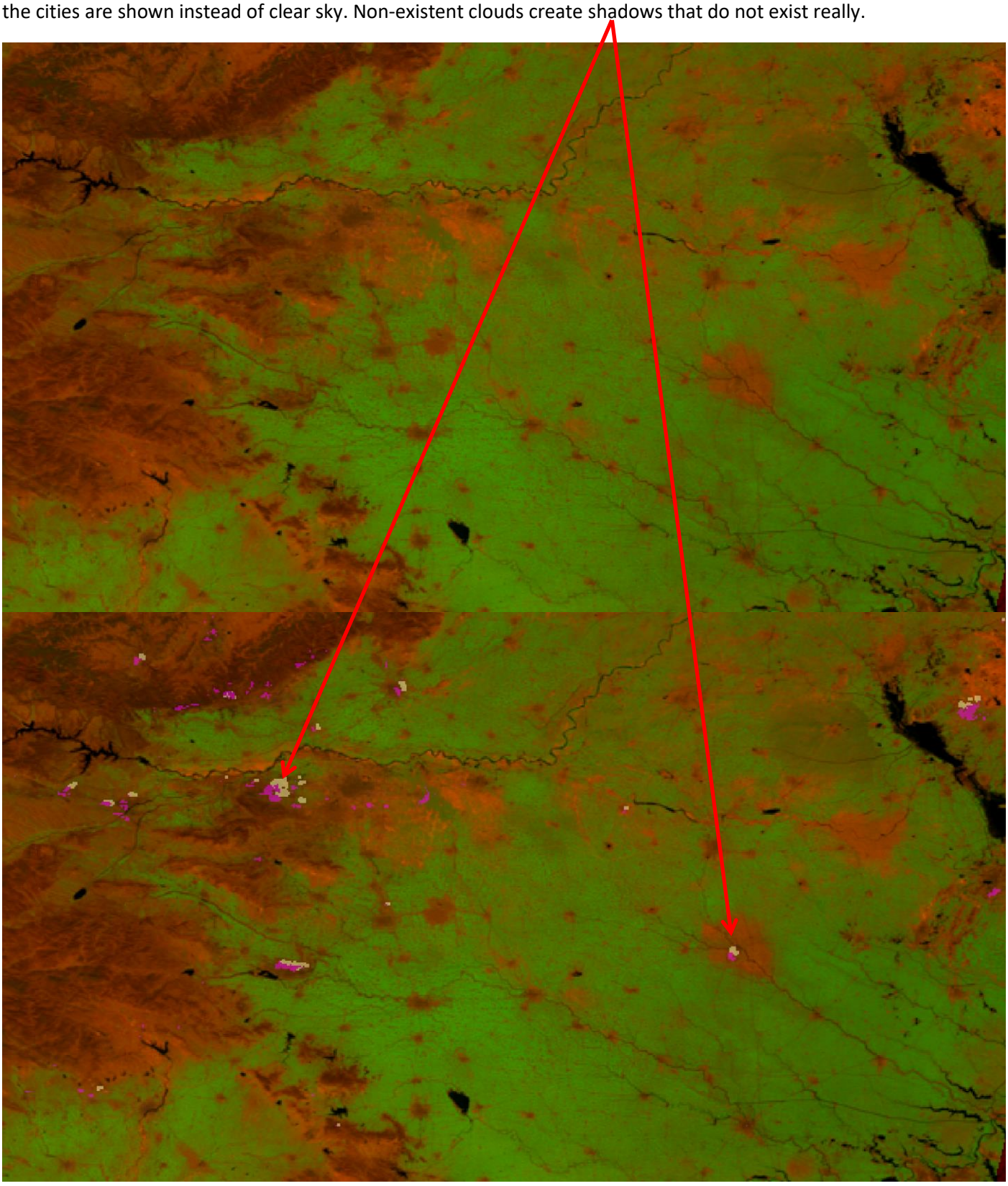
9. PROBAV_L2A_20140321_030005_3_1KM_V103 (Top: East Siberia; Bottom: Indochina ⊙ 9,0)



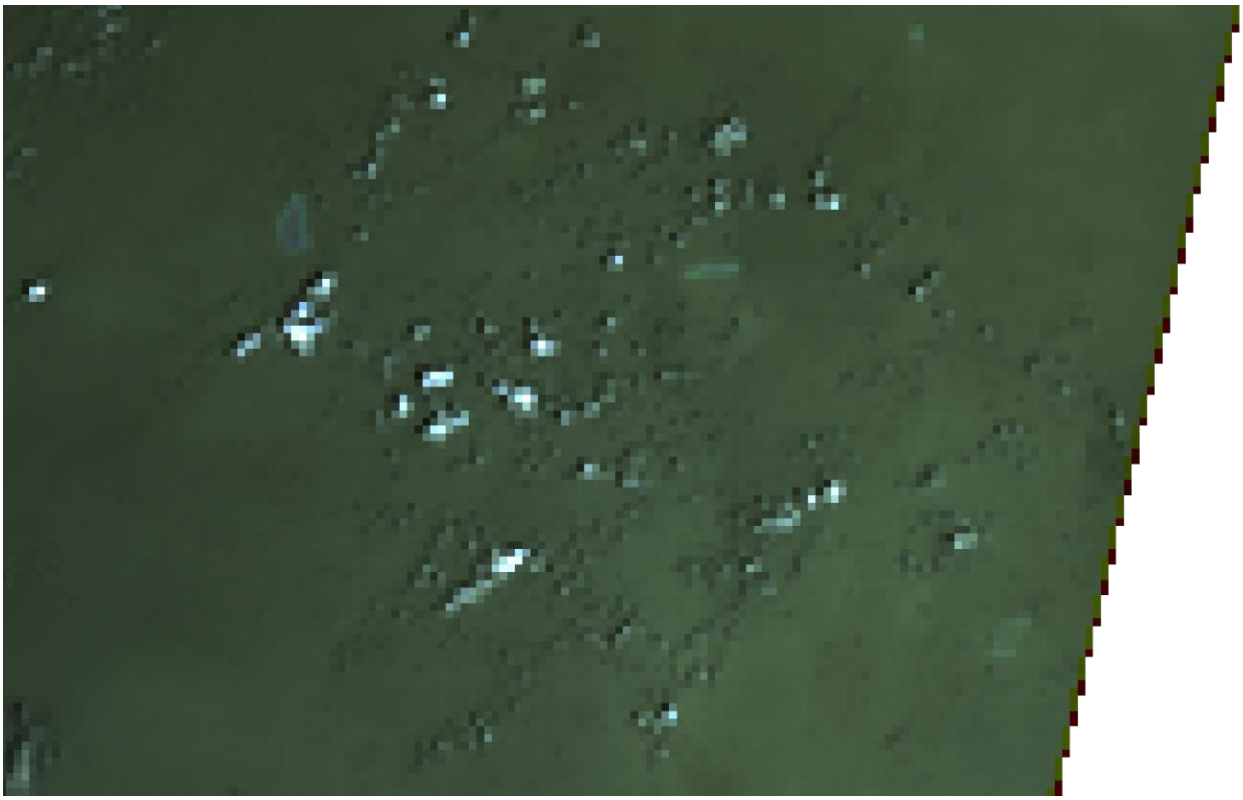
10. The same Fragment. Mist/haze well recognized! Shadows are only partially shown.

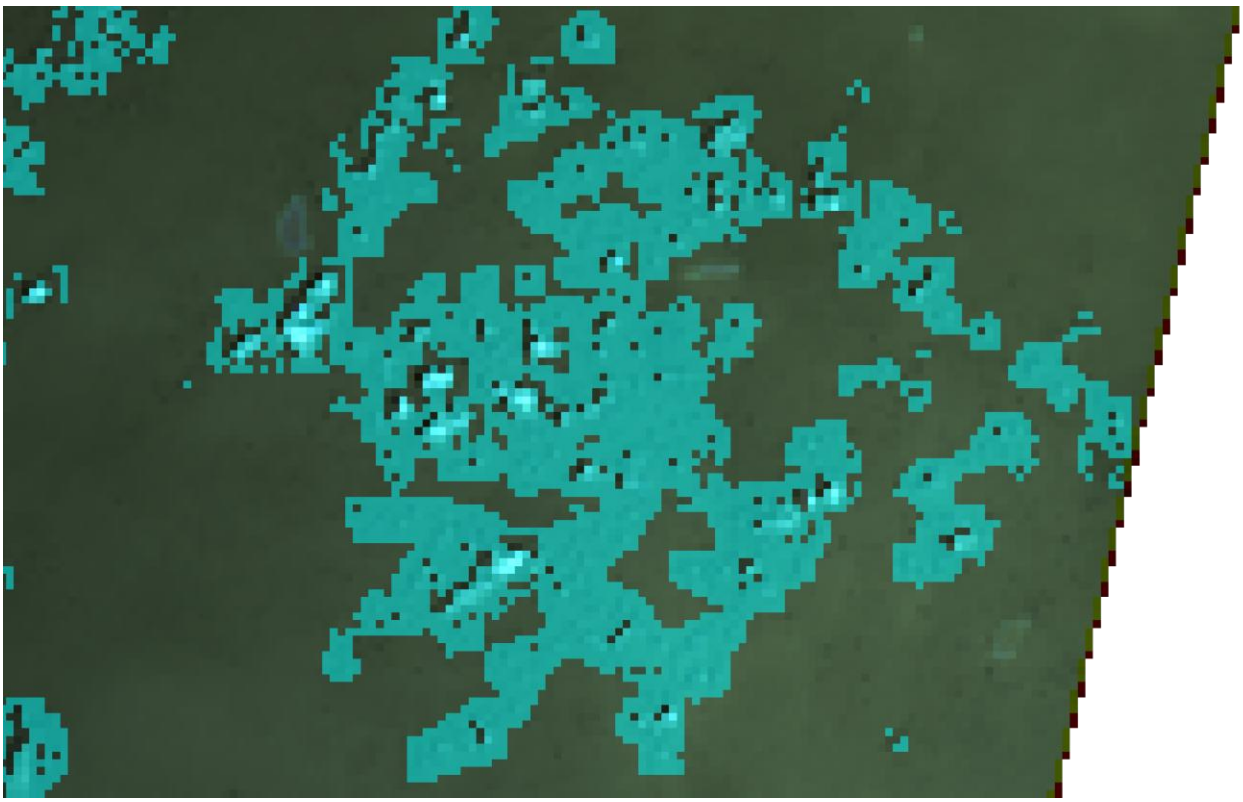


11. The same Fragment (Indian cities). Arrows show in my opinion incorrectly identified cloud pixels. Clouds above the cities are shown instead of clear sky. Non-existent clouds create shadows that do not exist really.

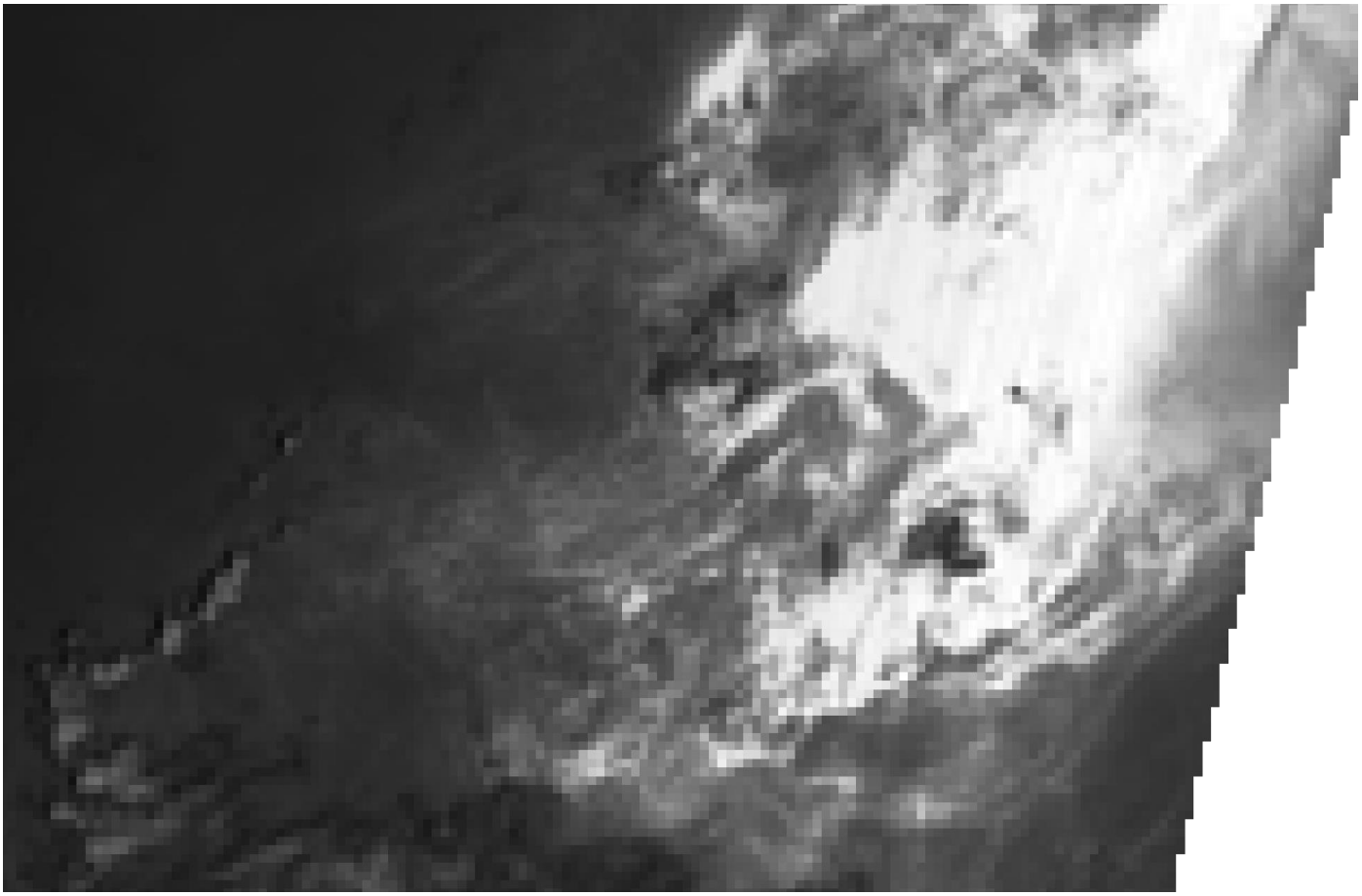


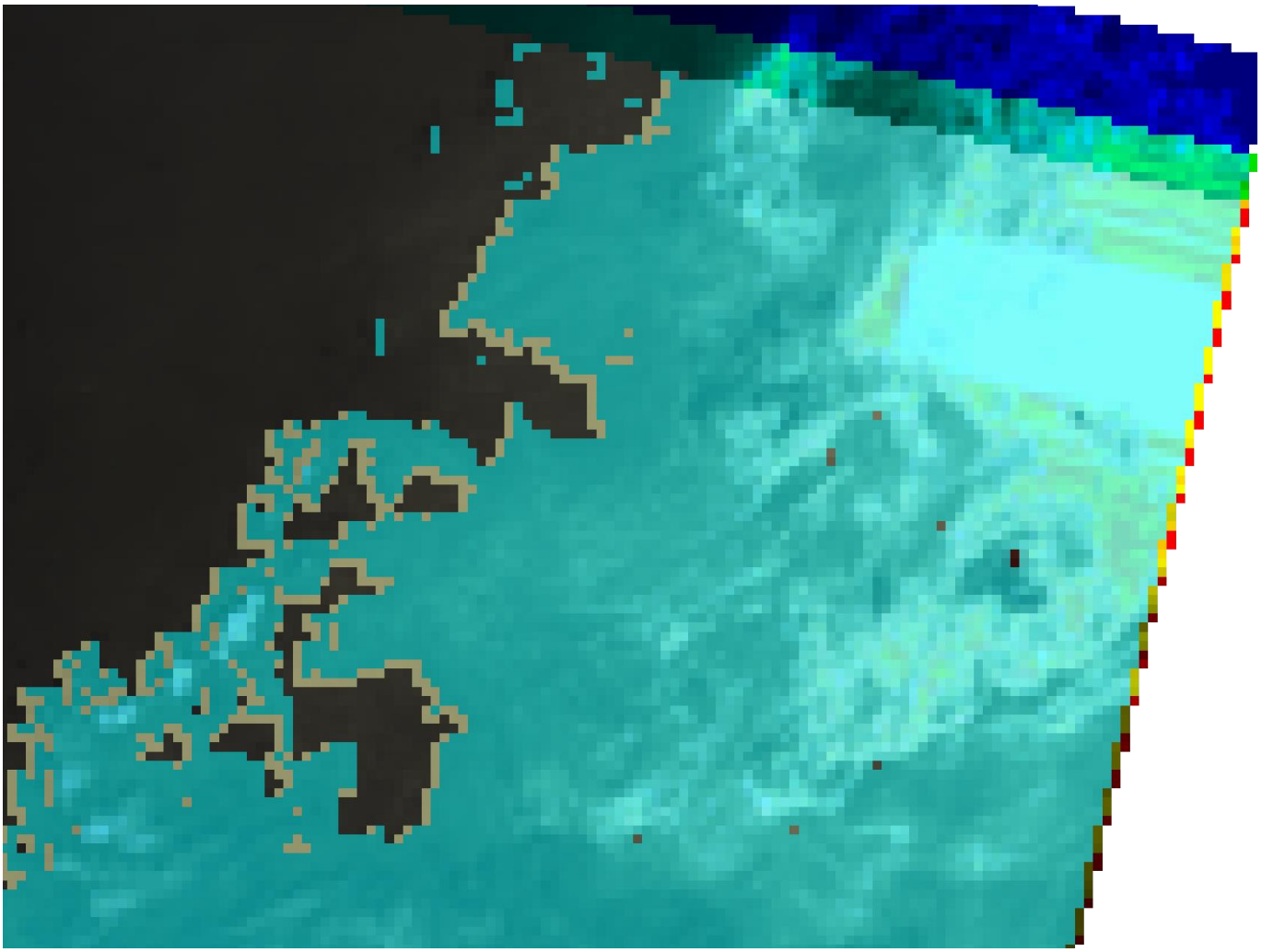
12. PROBAV_L2A_20140321_031830_2_1KM_V103 (Pacific Ocean)
Clouds are well recognized, but too coarse.
Many cloud-free pixels were marked as clouds.





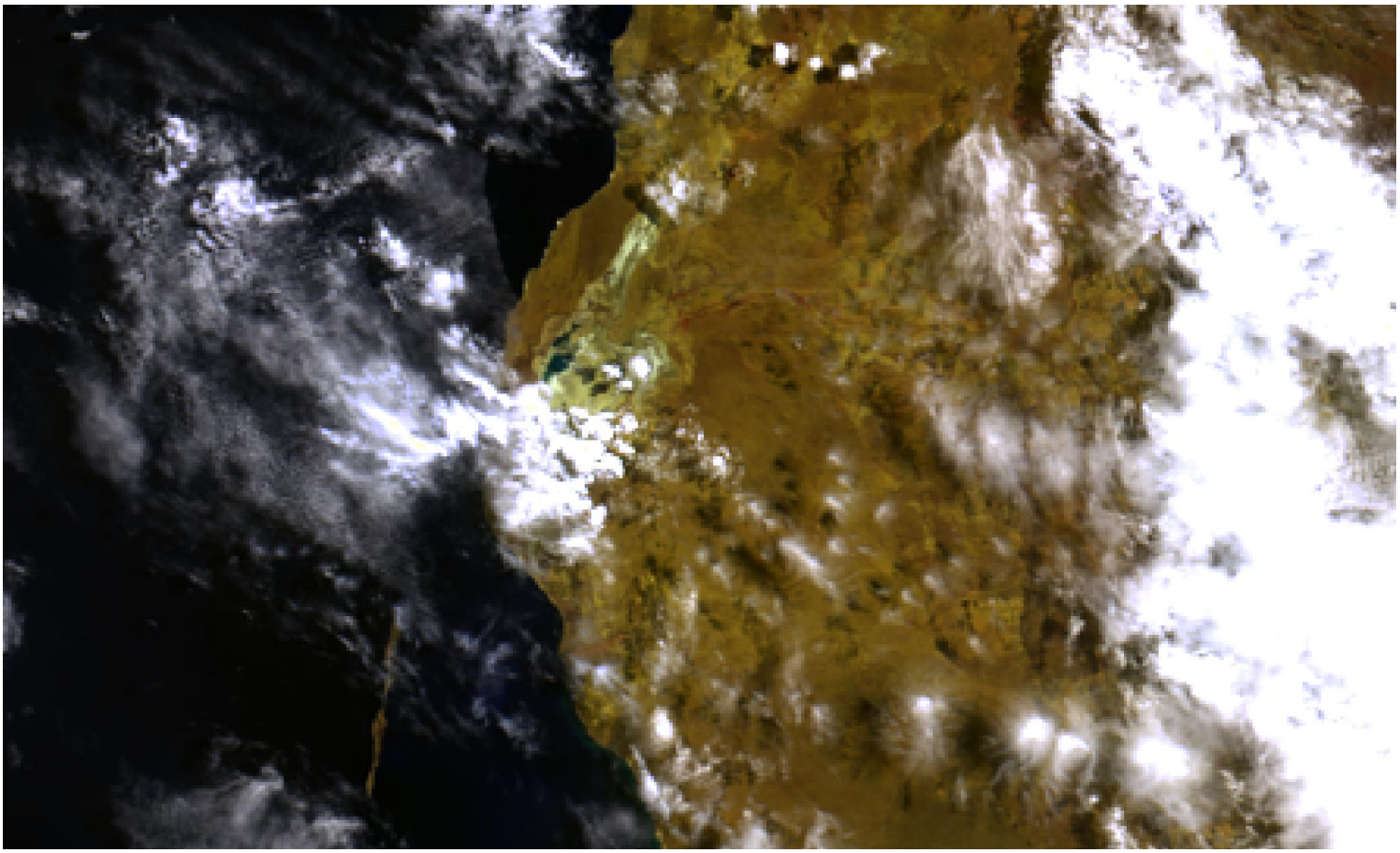
13. The same Fragment. Very many incorrect recognized (part oversaturated) sun glint pixels: clouds instead of free. And there are shadows from clouds that do not exist.

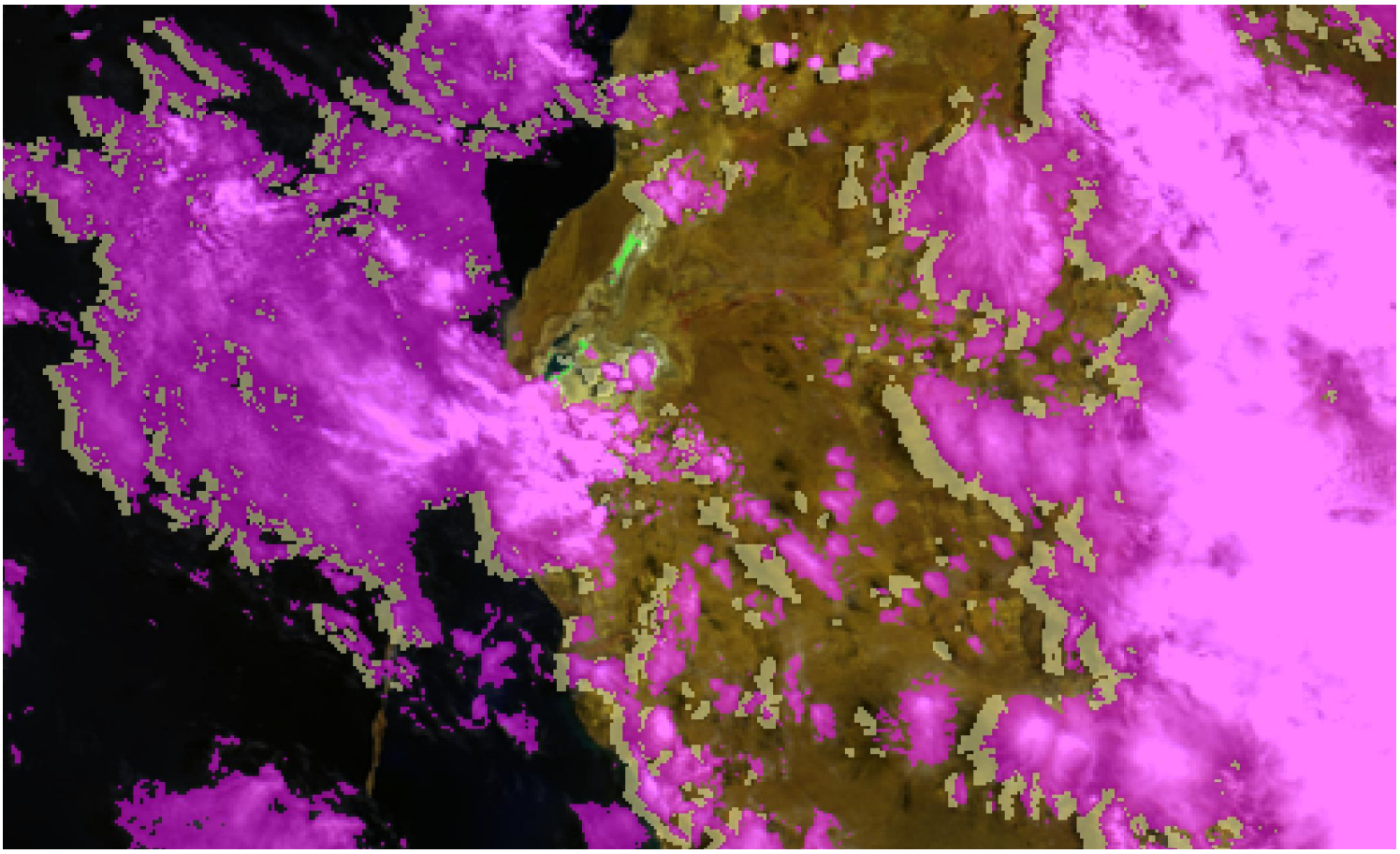




14. PROBAV_L2A_20140321_032645_1_1KM_V103 (West Australia)

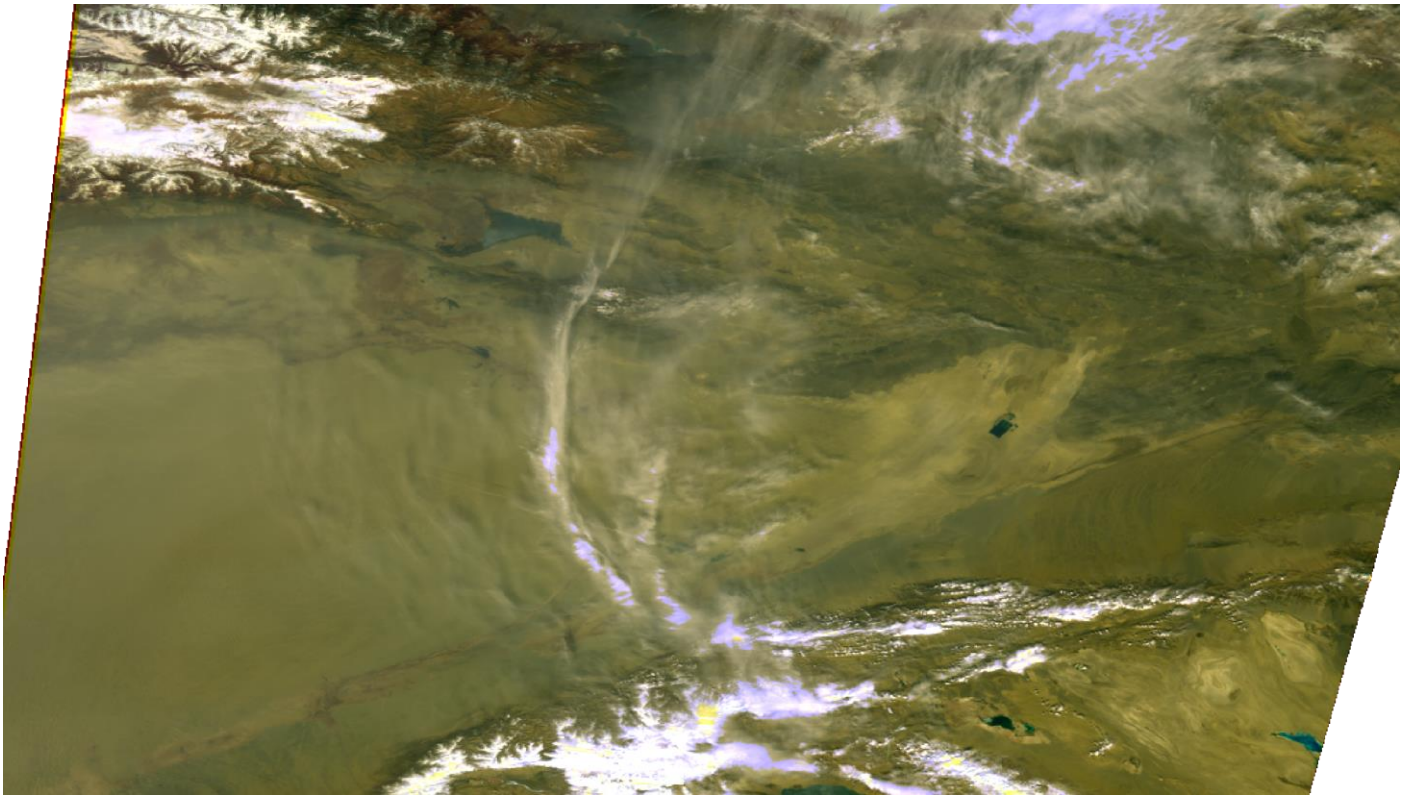
Clouds have been well recognized. Cloud shadows are reasonable. It should be noted that the shadows stick to the associated clouds, which is not always correct.

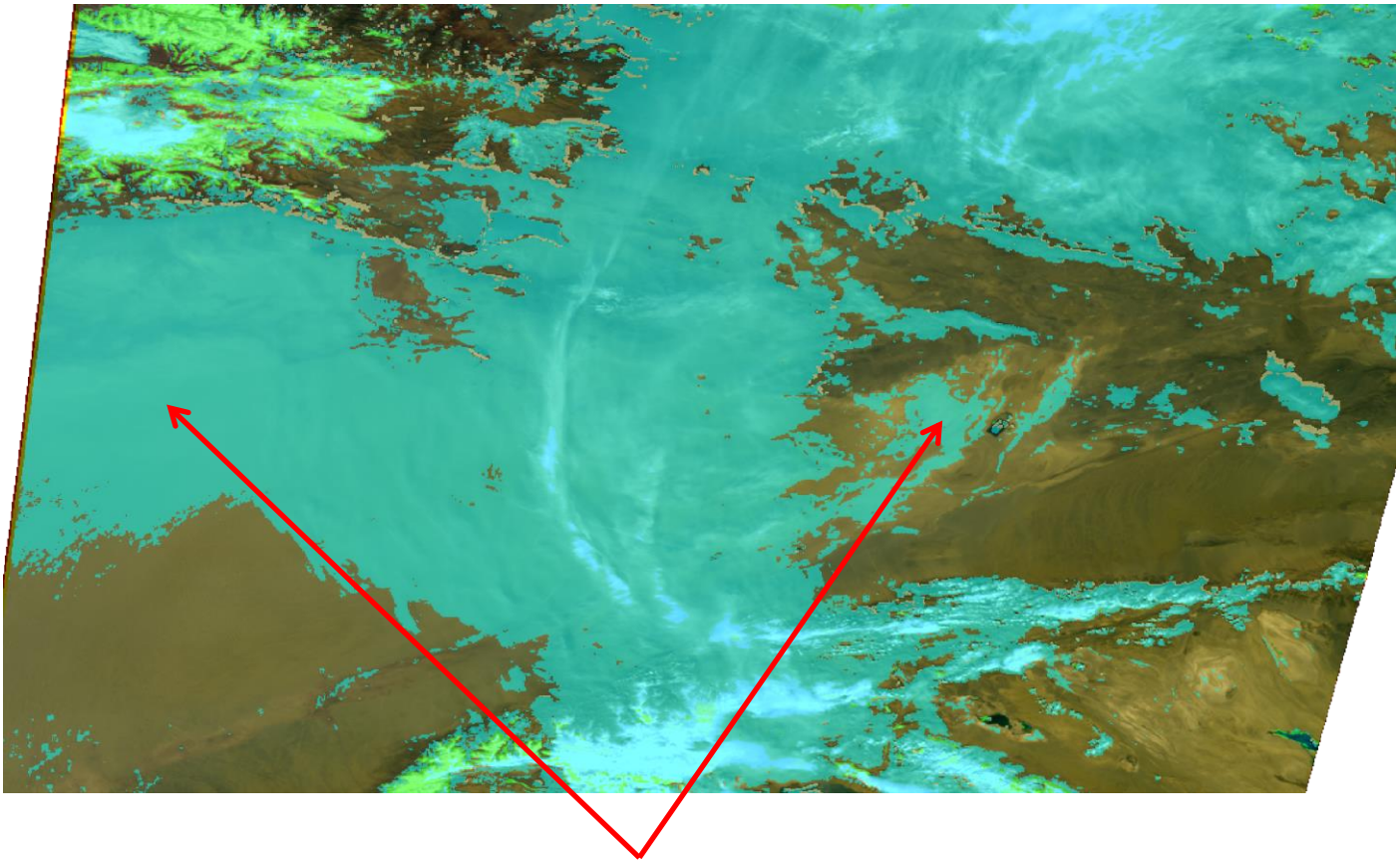




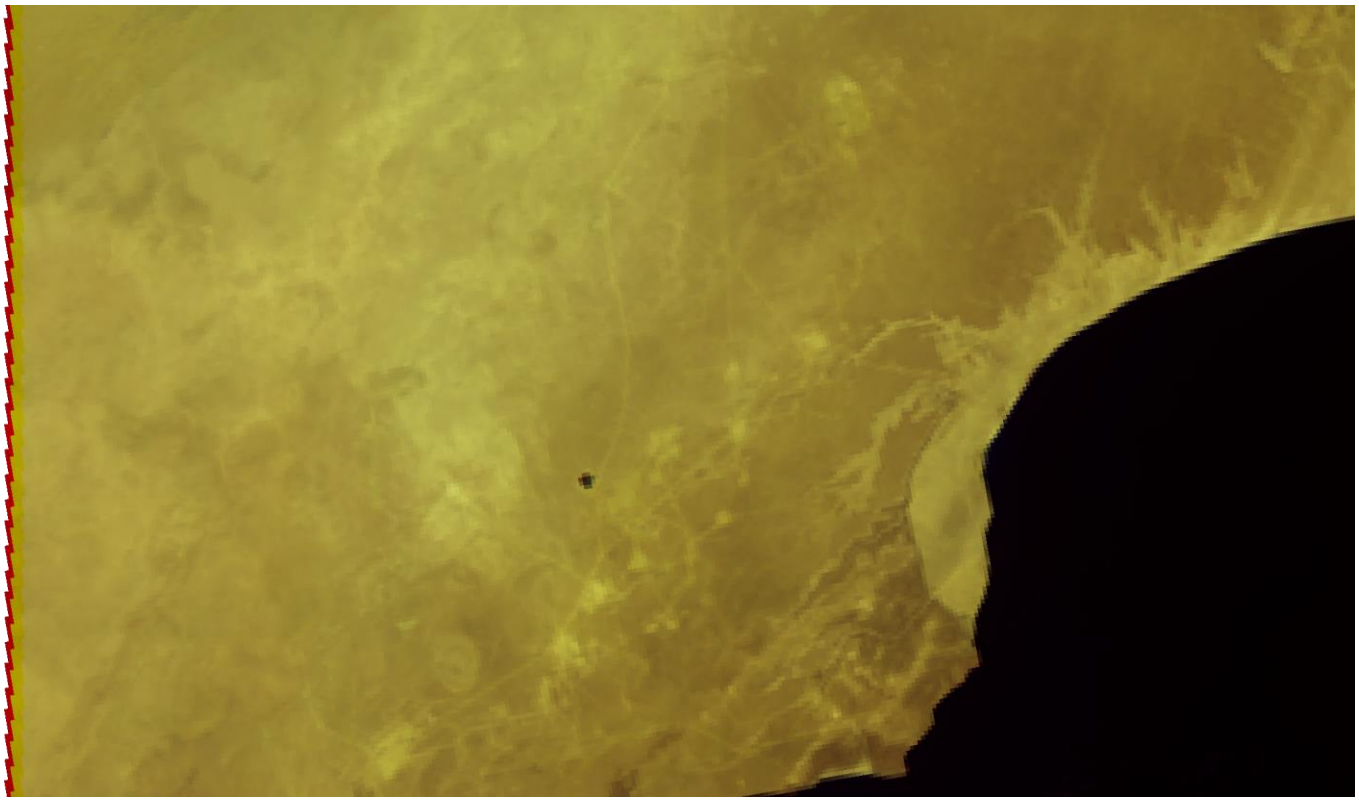
15. PROBAV_L2A_20140321_044105_3_1KM_V103 (Desert Takla Makan)

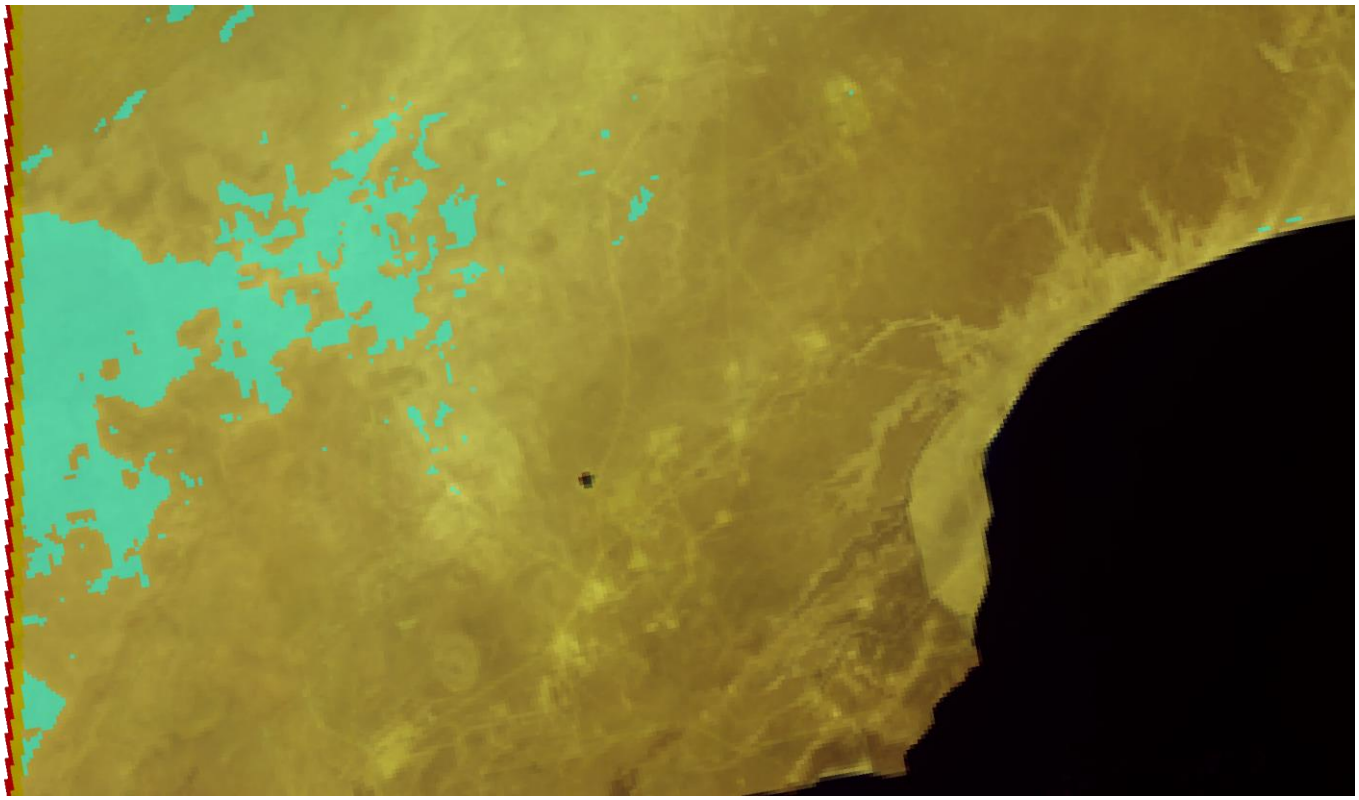
Part of the desert, rather doubtfully, was marked as cloudy. Perhaps is understood as sand dust?



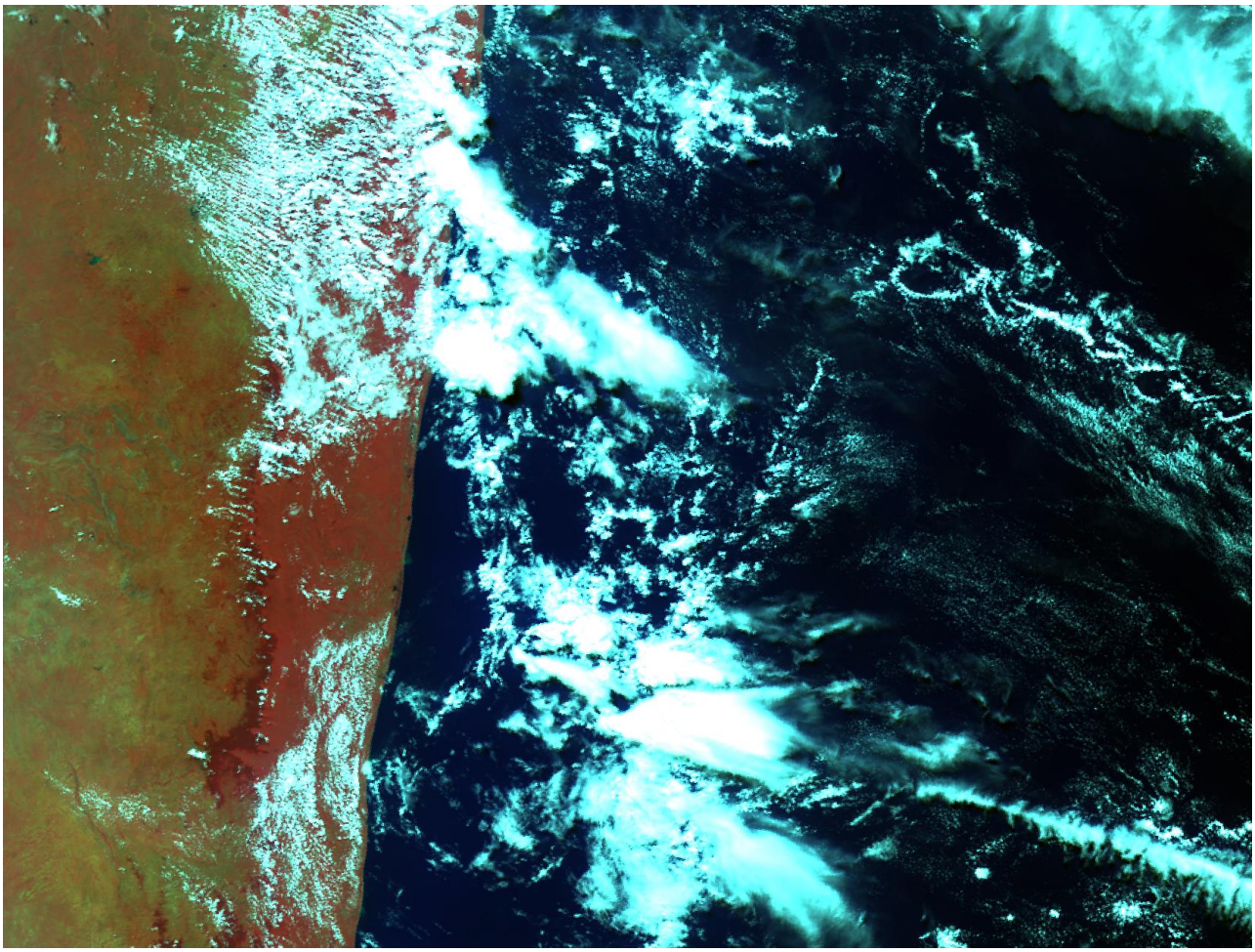


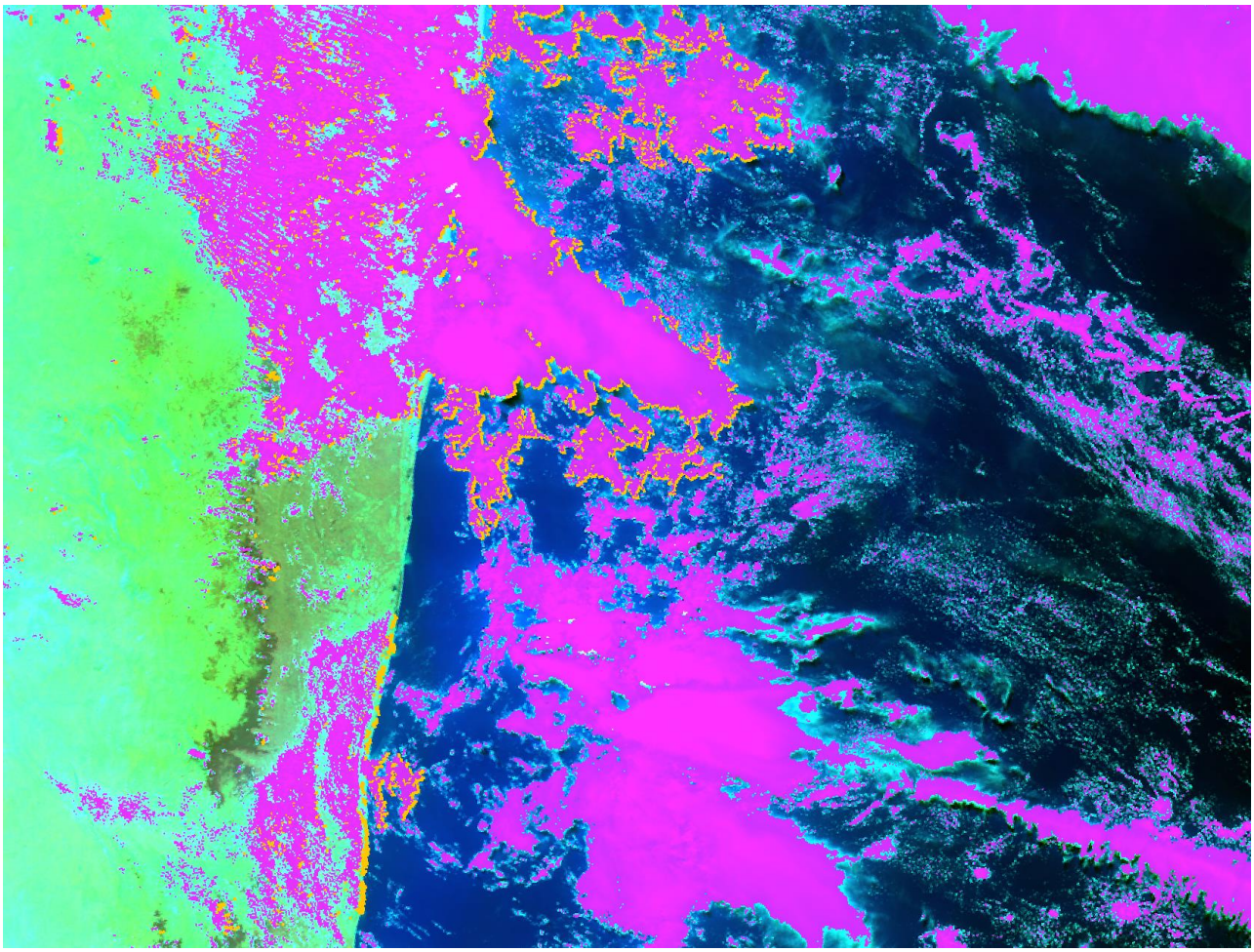
16. PROBAV_L2A_20140321_062221_3_1KM_V103 (Southeast of Arabian Peninsula)
Part of the desert was wrong marked as cloudy in my opinion.



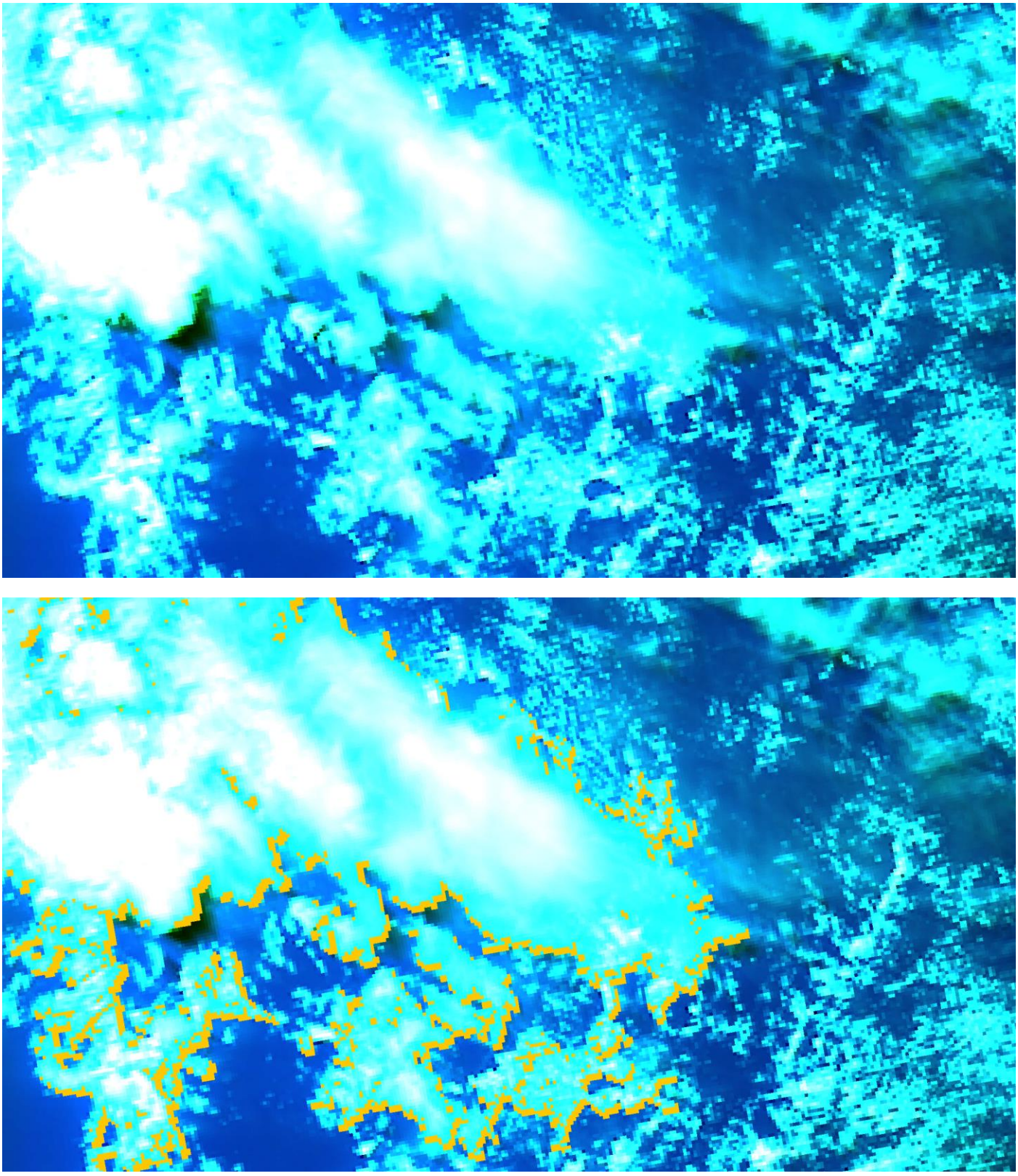


17. PROBAV_L2A_20140321_064750_3_1KM_V103 (East Coast of Madagascar)
Not all (although very thin) clouds are marked as such.



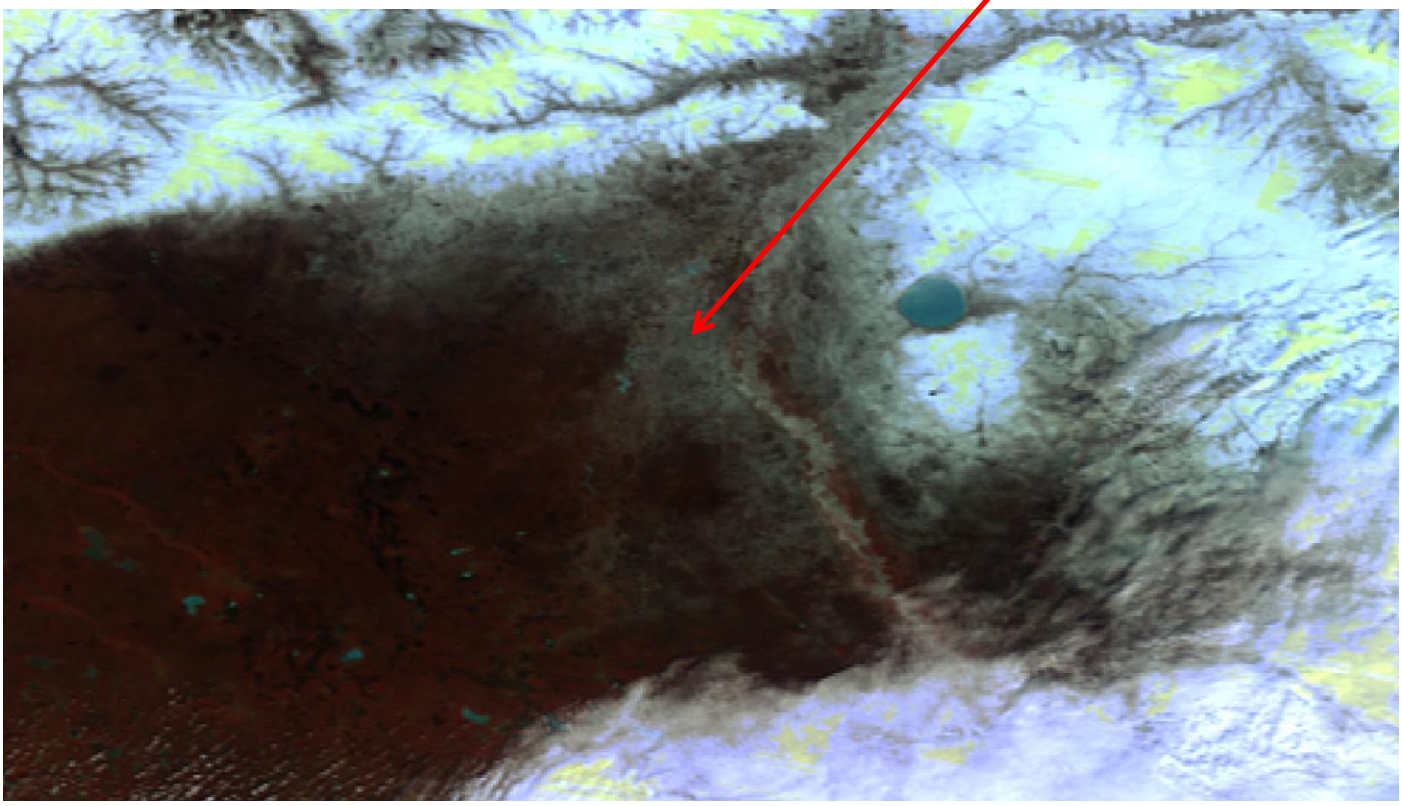


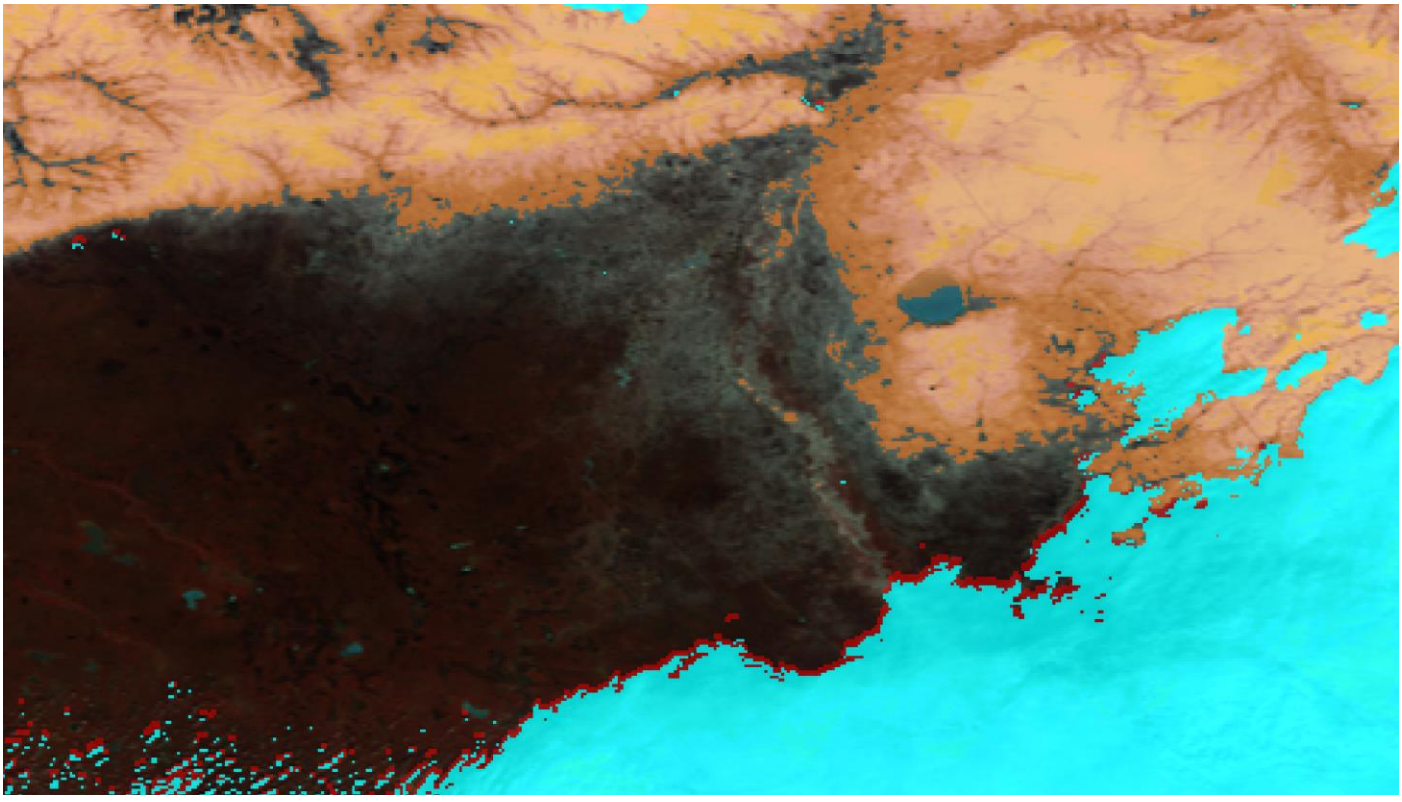
18. The same Fragment. Shadow sizes are defined incorrectly. Perhaps the algorithm uses only one standard height of the top cloud surface (ca. 3km). On the right fragment side, shadows are not identified at all, although they are there.



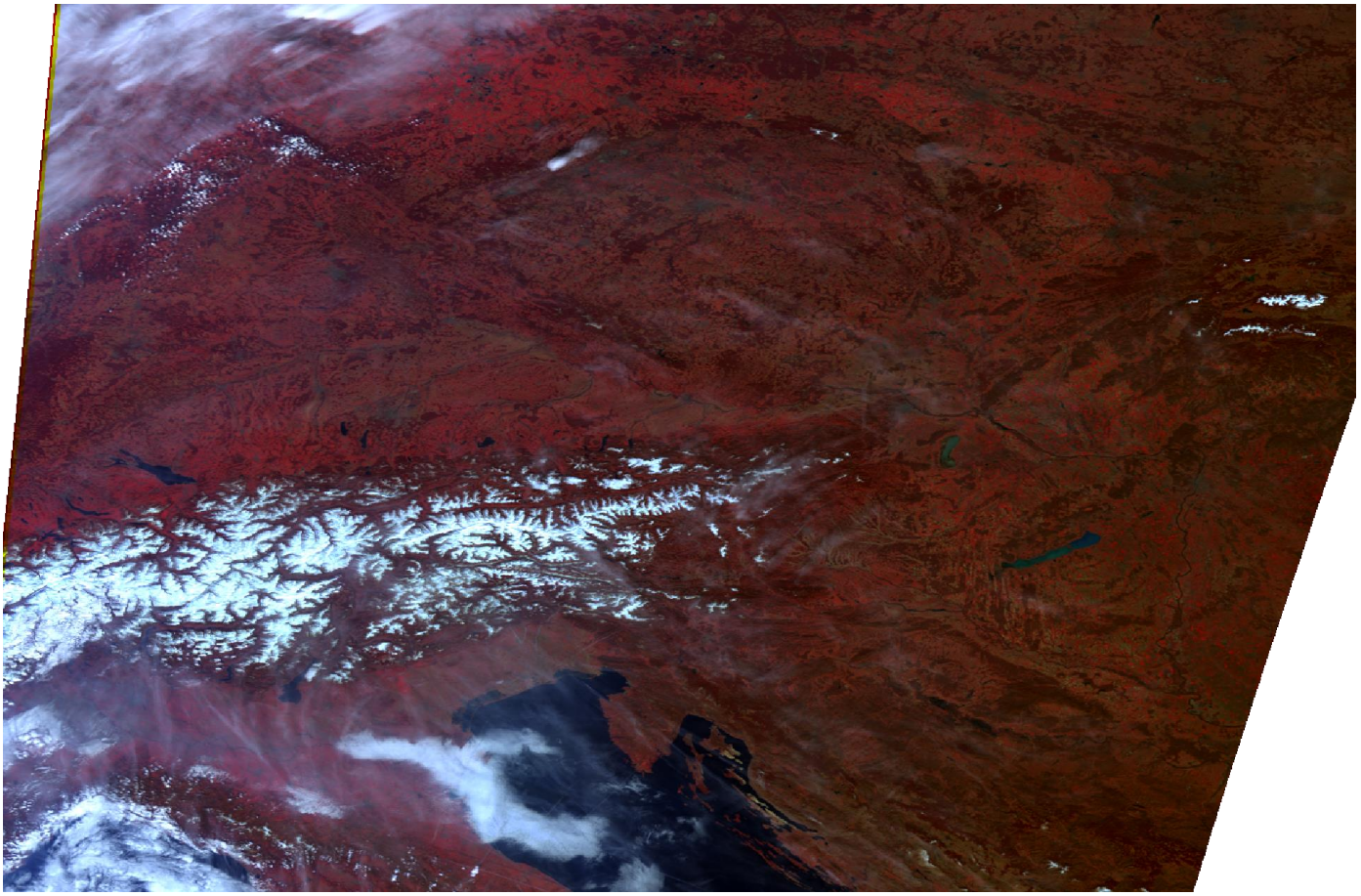
19. PROBAV_L2A_20140321_080358_2_1KM_V103 (Northwest of Kazakhstan)

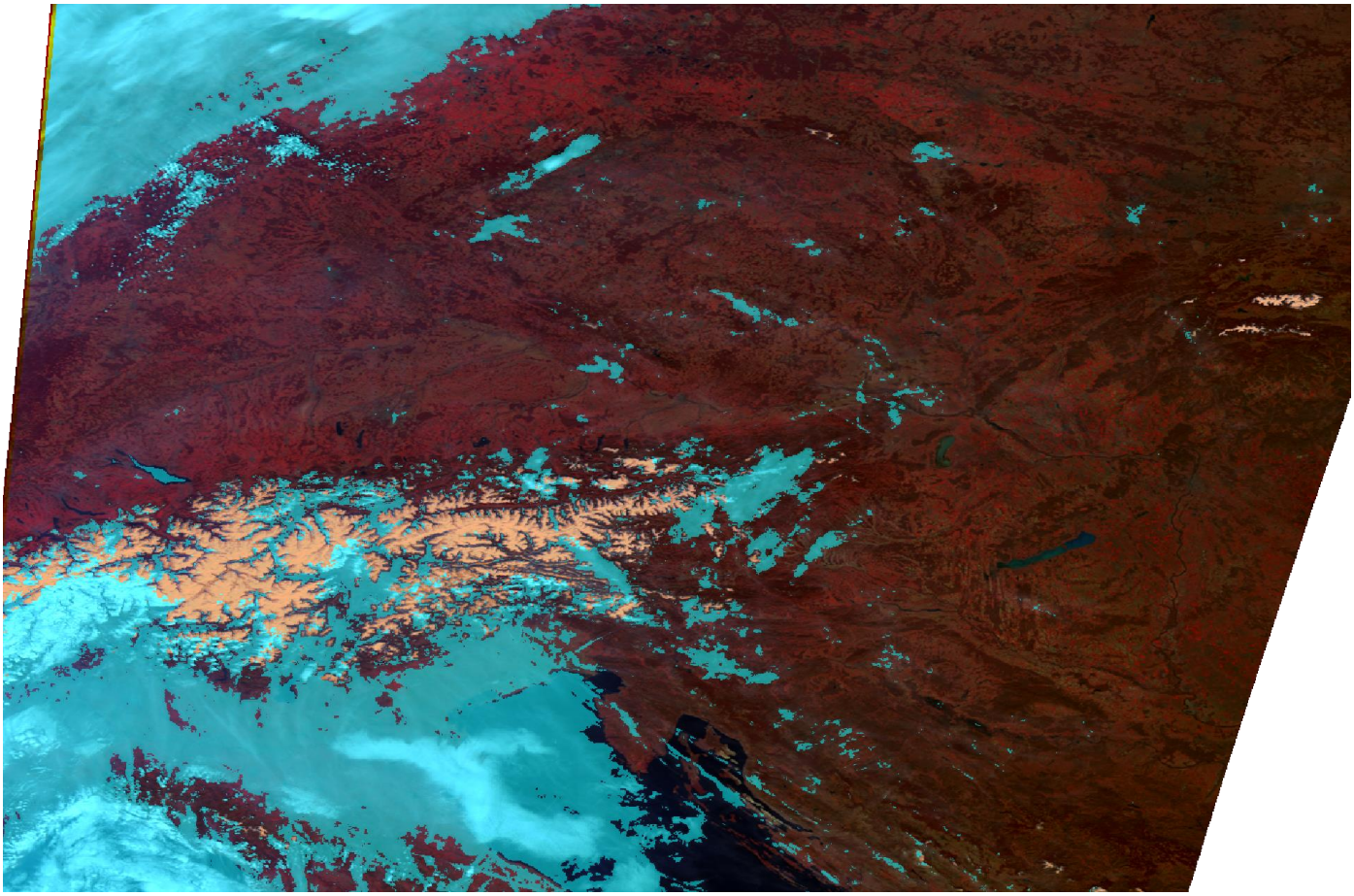
The “spatially-mixed” snow covered steppe was not identified as such. Otherwise the clouds and snow have been well separated. Shadows - OK, because the clouds are not high.



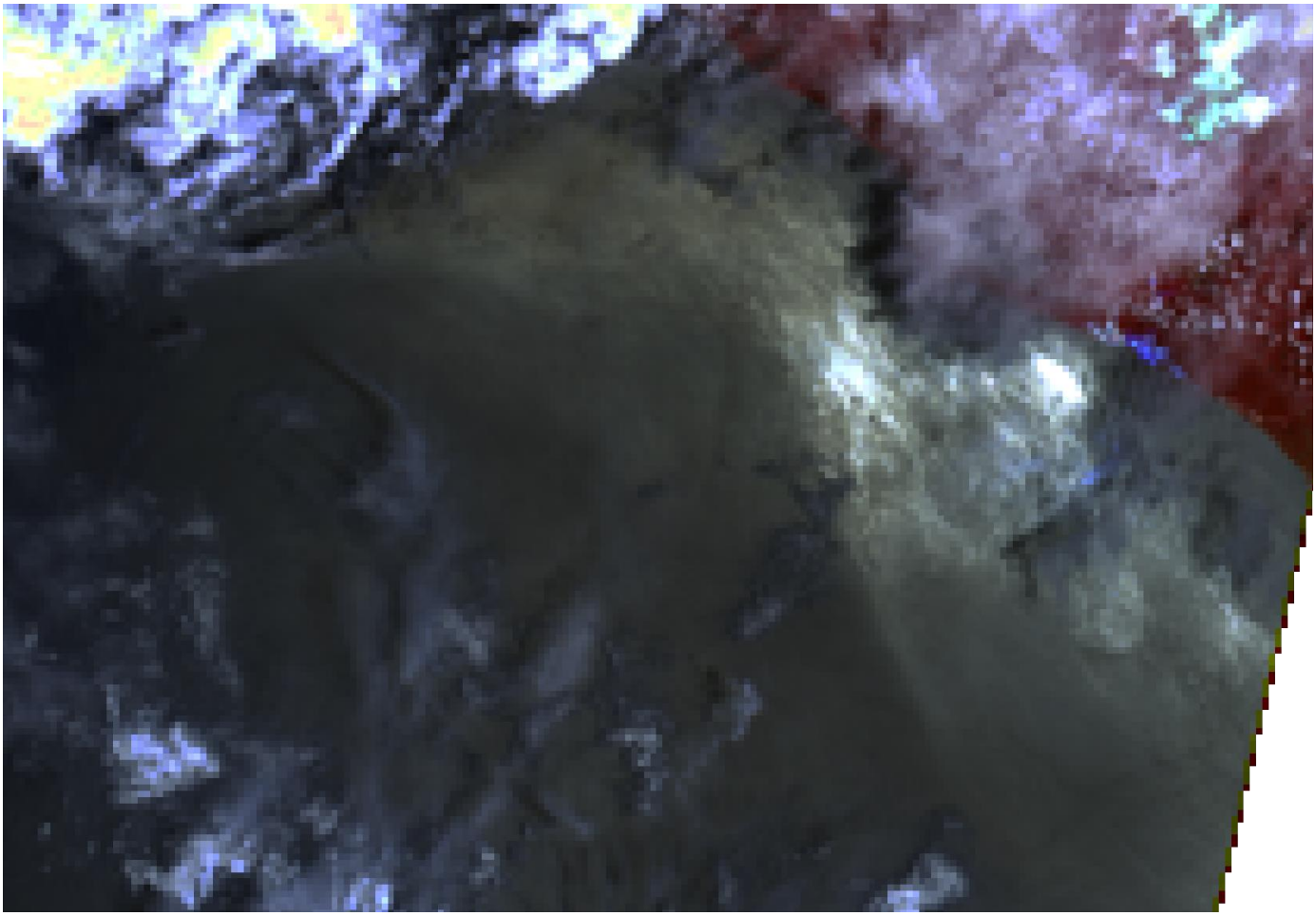


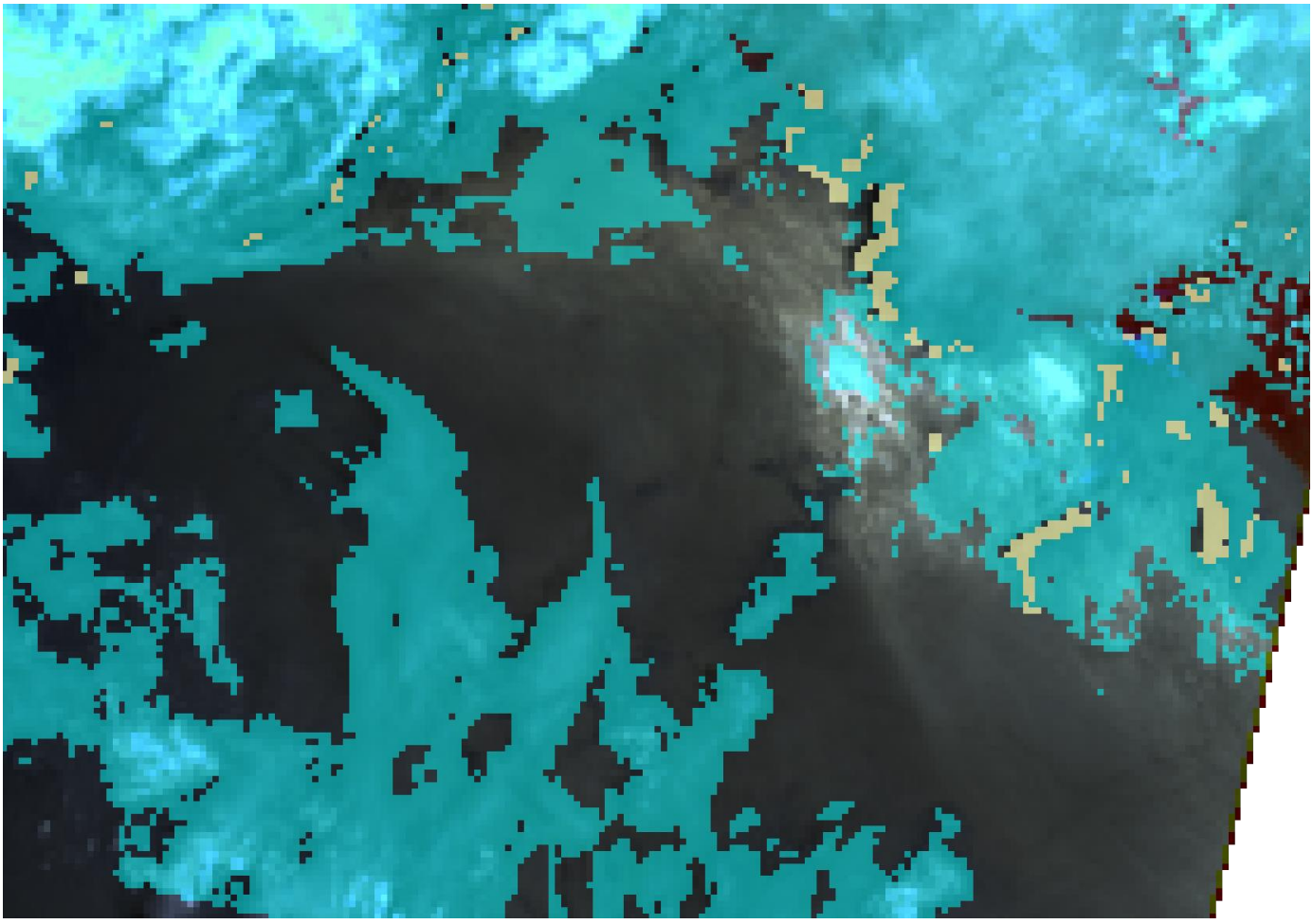
20. PROBAV_L2A_20140321_080358_2_1KM_V103 (East of Alps, North of Adriatic Sea)
Thin clouds over the mountains are well recognized.



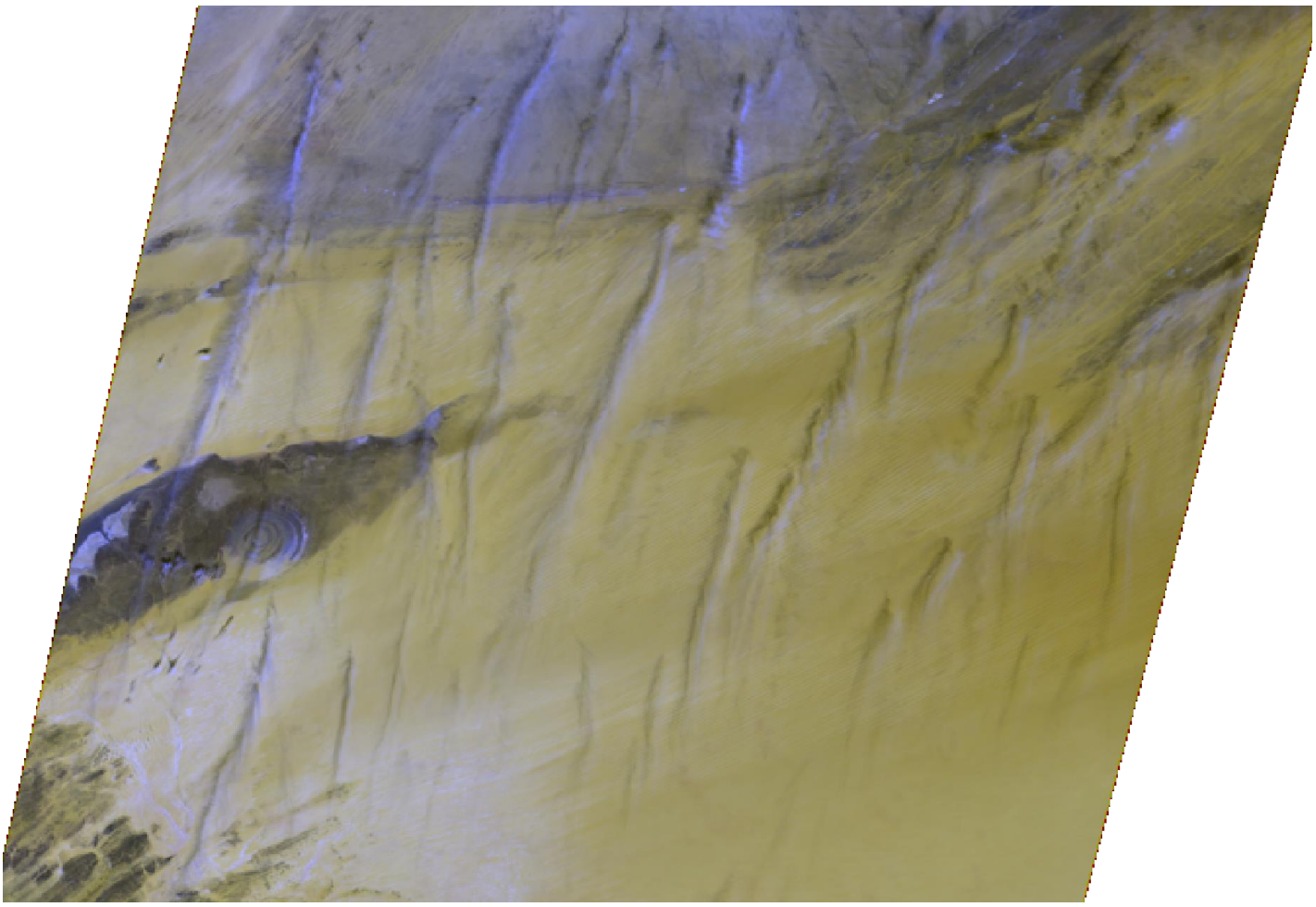


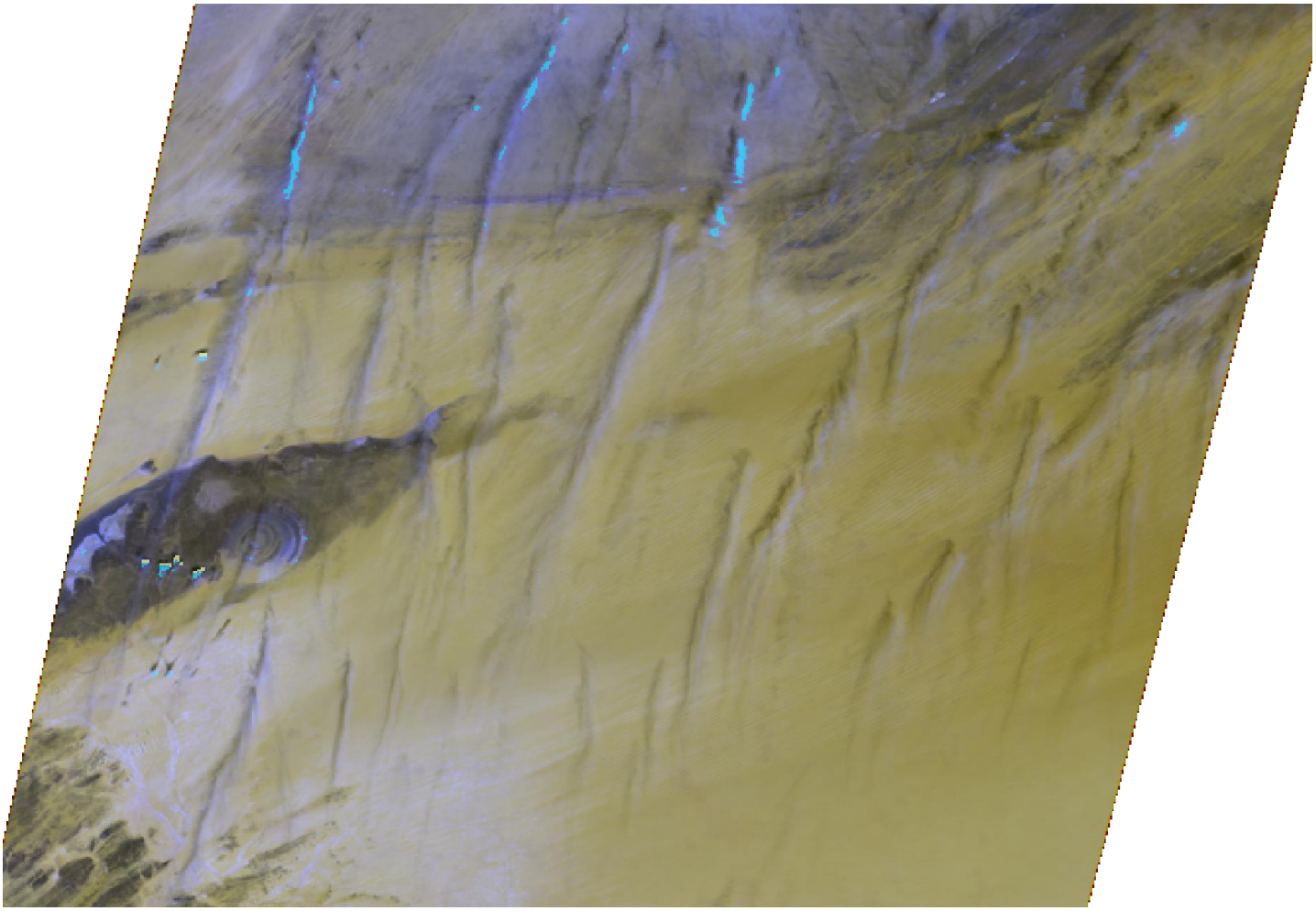
21. PROBAV_L2A_20140321_112632_2_1KM_V103 (Atlantic Ocean, West Africa, Liberia Coast)
Sun glint was incorrectly recognized as clouds. Shadow size is too narrow due to incorrect estimation of the cloud height.



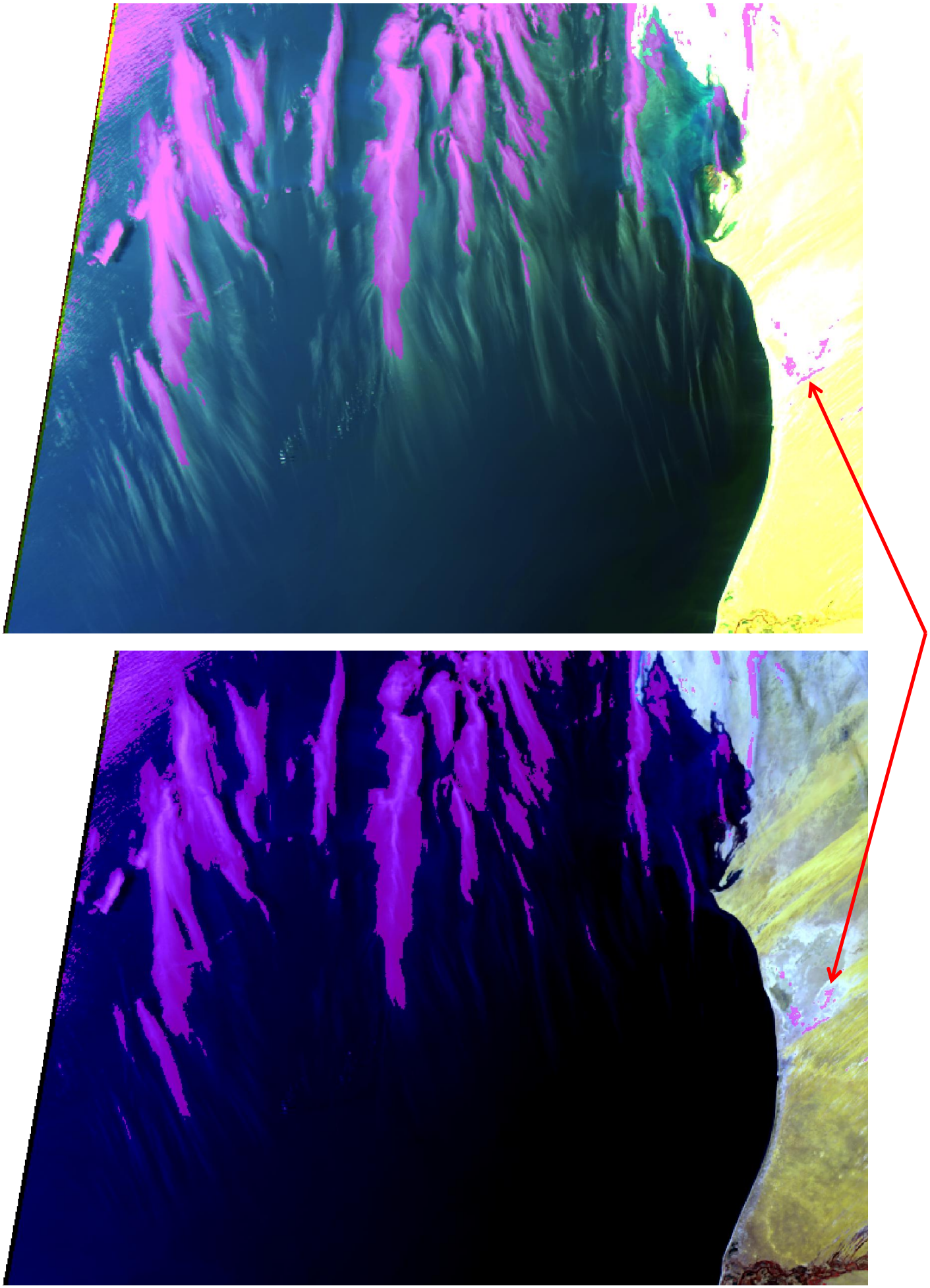


22. The same Fragment. Clearly visible semi-transparent clouds (over Western Sahara) were not masked. Gross mistake.





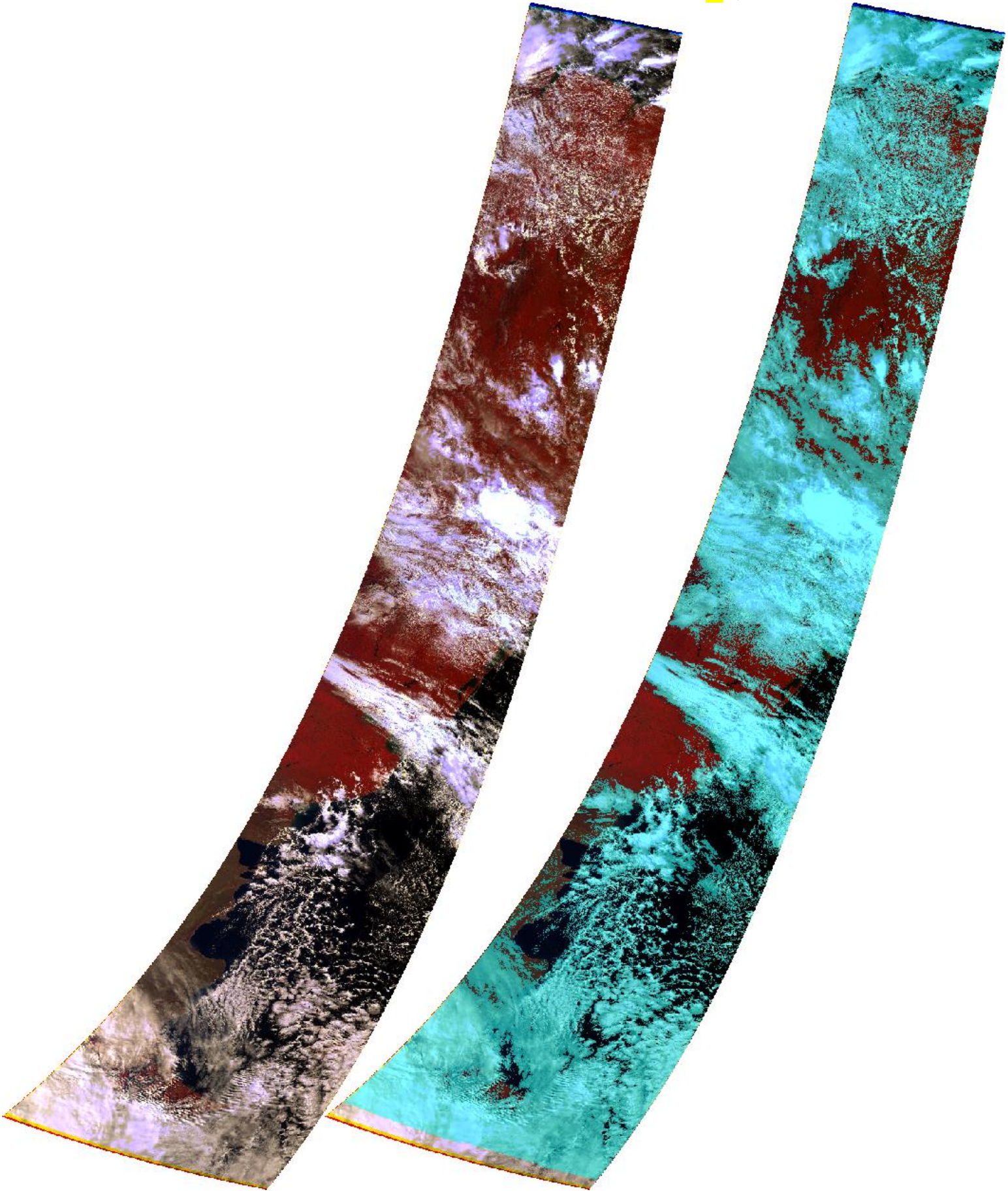
23. PROBAV_L2A_20140321_113854_3_1KM_V103 (Atlantic Sea, West Africa, Mauretania Coast)
Thin clouds over the sea are recognized not well enough.
Light salt lake pixels(on the right) was masked as a cloud.



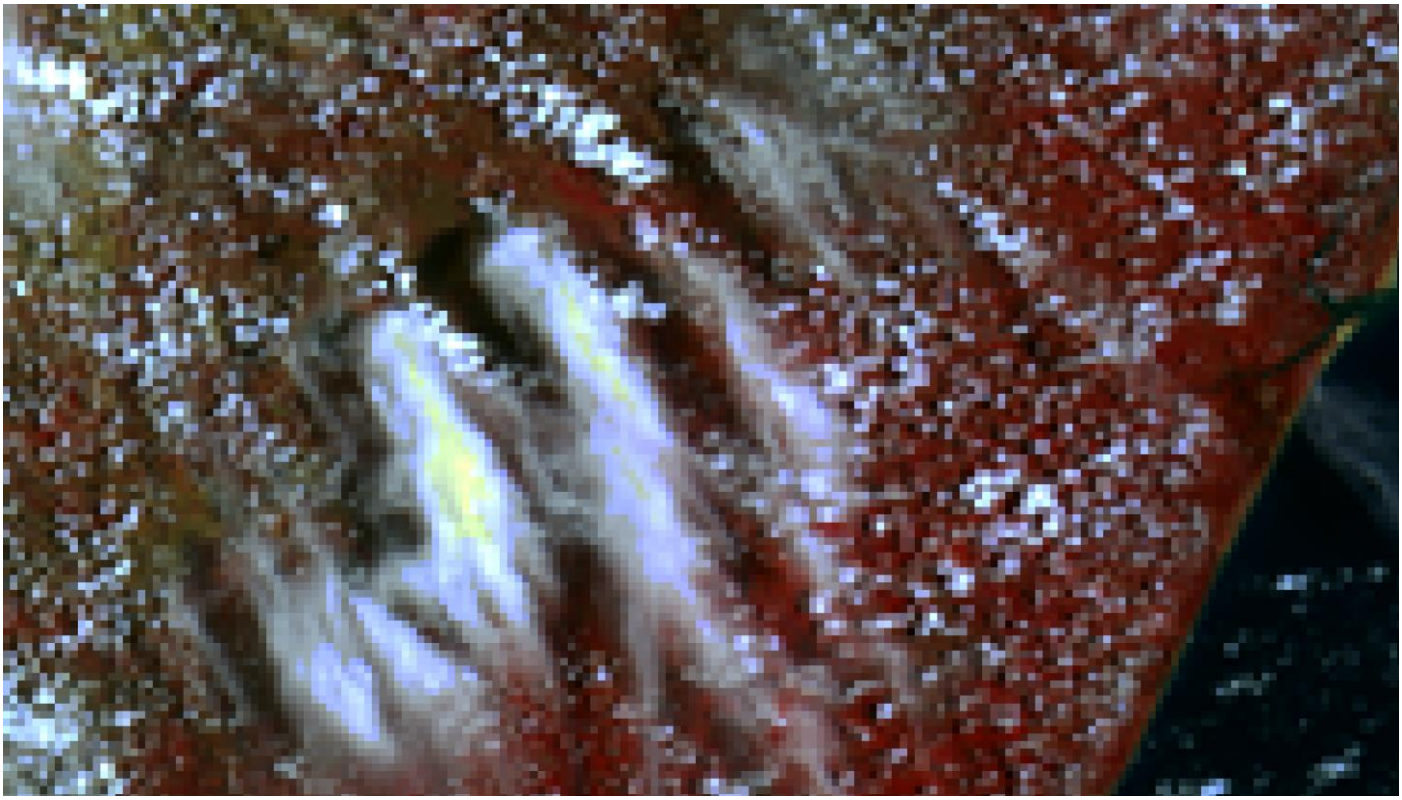
24. PROBAV_L2A_20140321_132915_3_1KM_V103 (East of South America, Brazil)

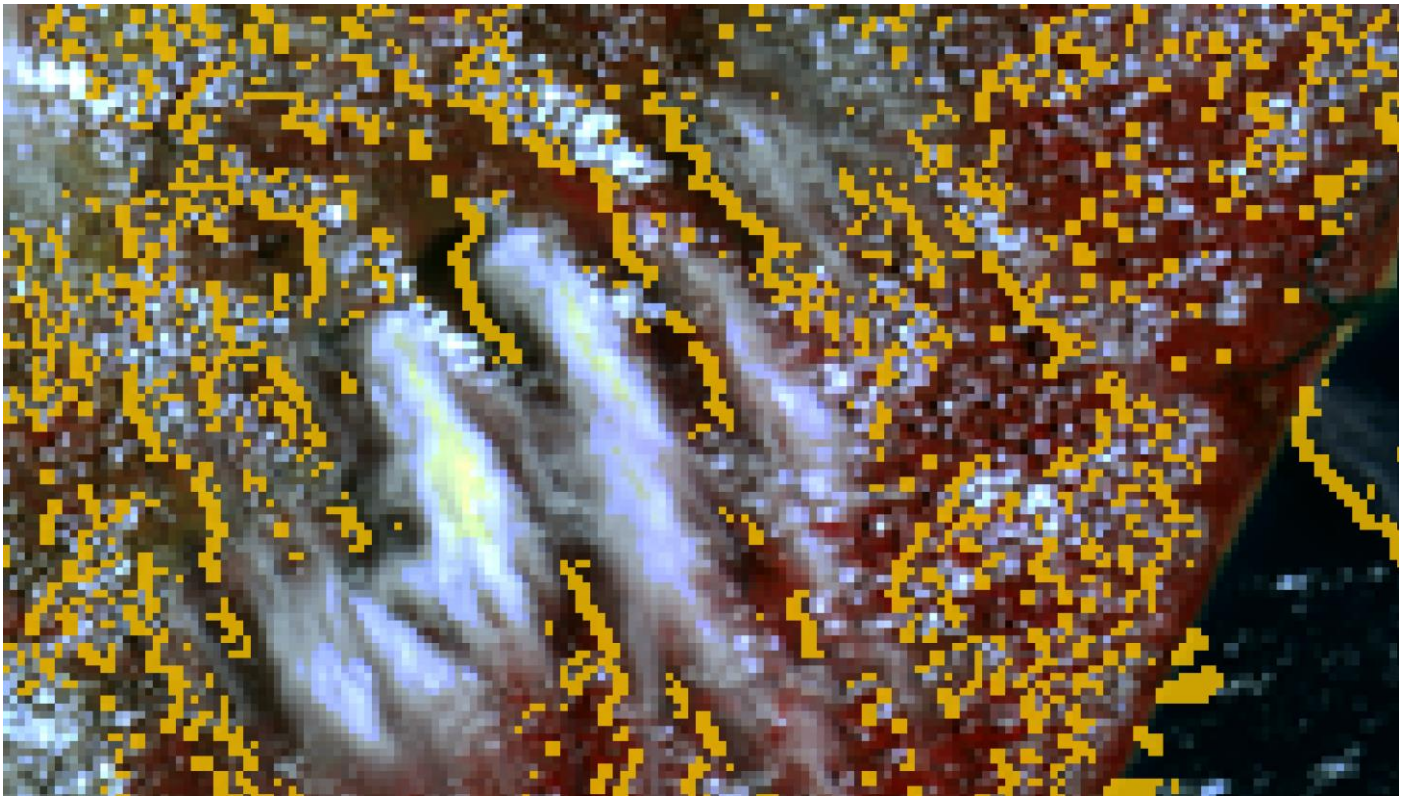
A good cloud mask.

⊙ 9,0



25. PROBAV_L2A_20140321_133010_1_1KM_V103 (South America, Brazil, State of Bahia)
Cloud shadows are partly too skimpy due to incorrect cloud height estimation.

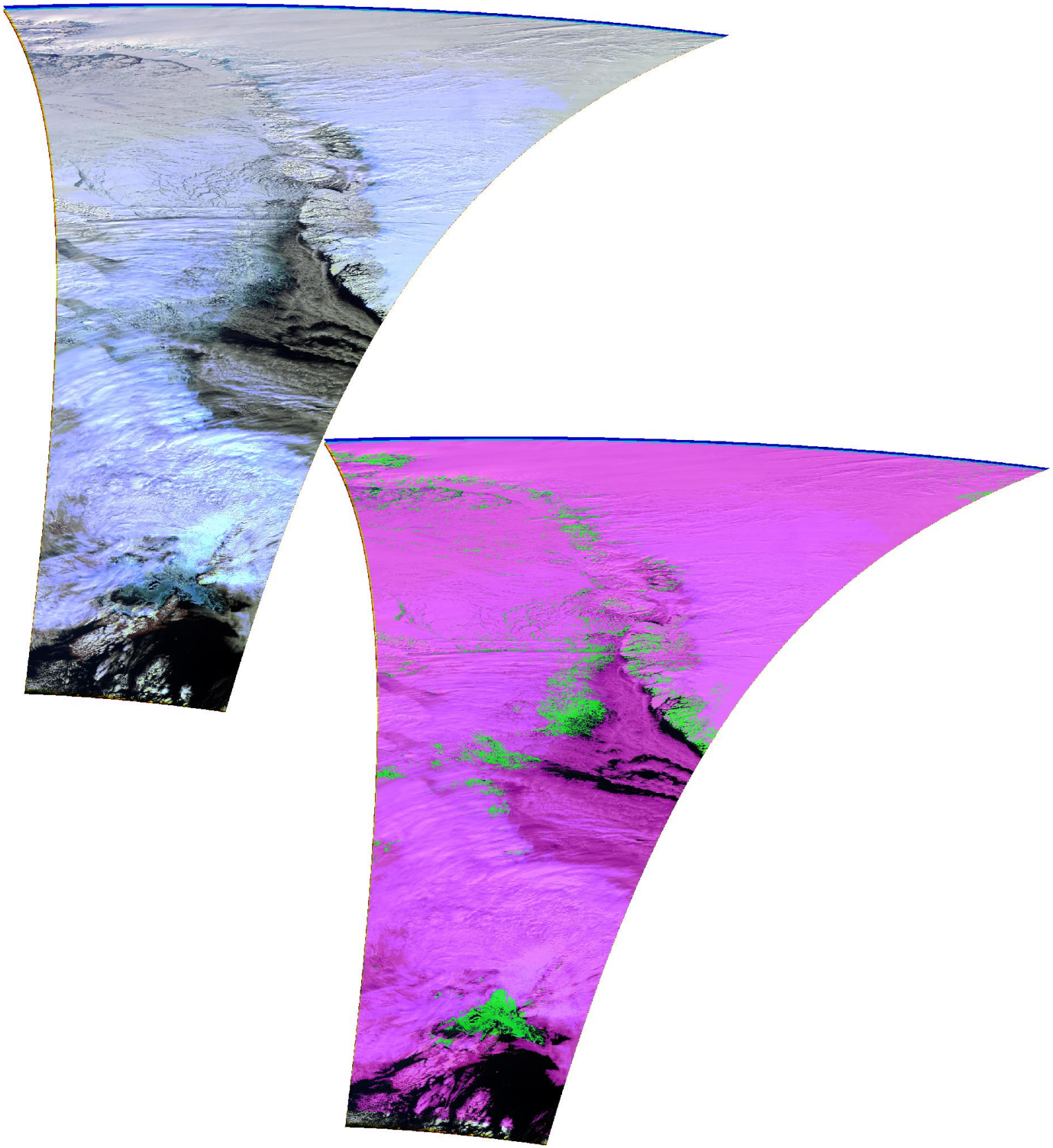




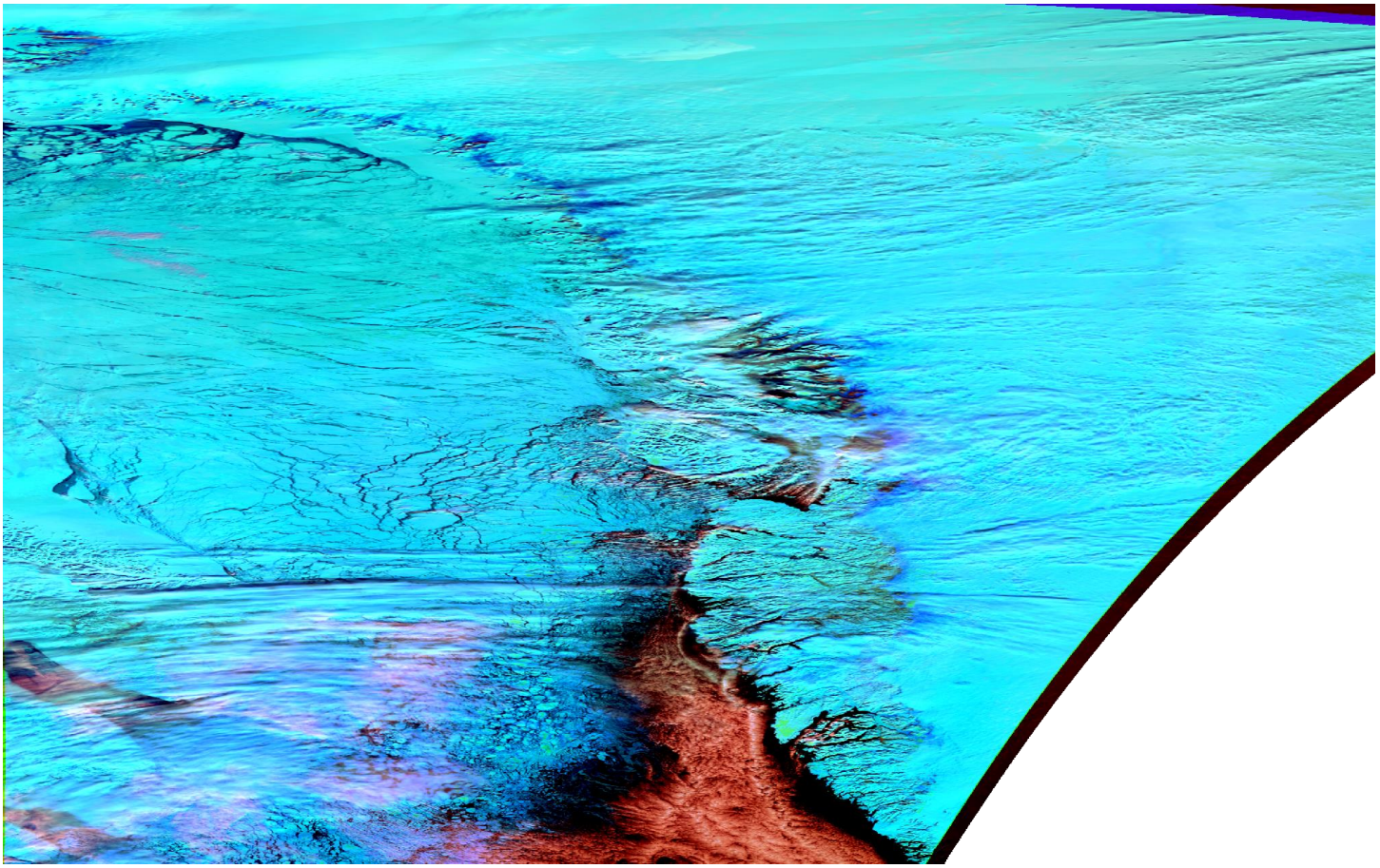
I thing that when determining the shadow size, only the height of the clouds is taken into account.
I suppose this height is not found or calculated, but some standard height, presumably about 3 km, was taken.
The darkening of the surface due to its shading is not taken into account at all.

26. PROBAV_L2A_20140321_144841_3_1KM_V103 (West Greenland, Davis Strait)
A lot of clear sky land ice and sea ice pixels are wrongly marked as cloudy.

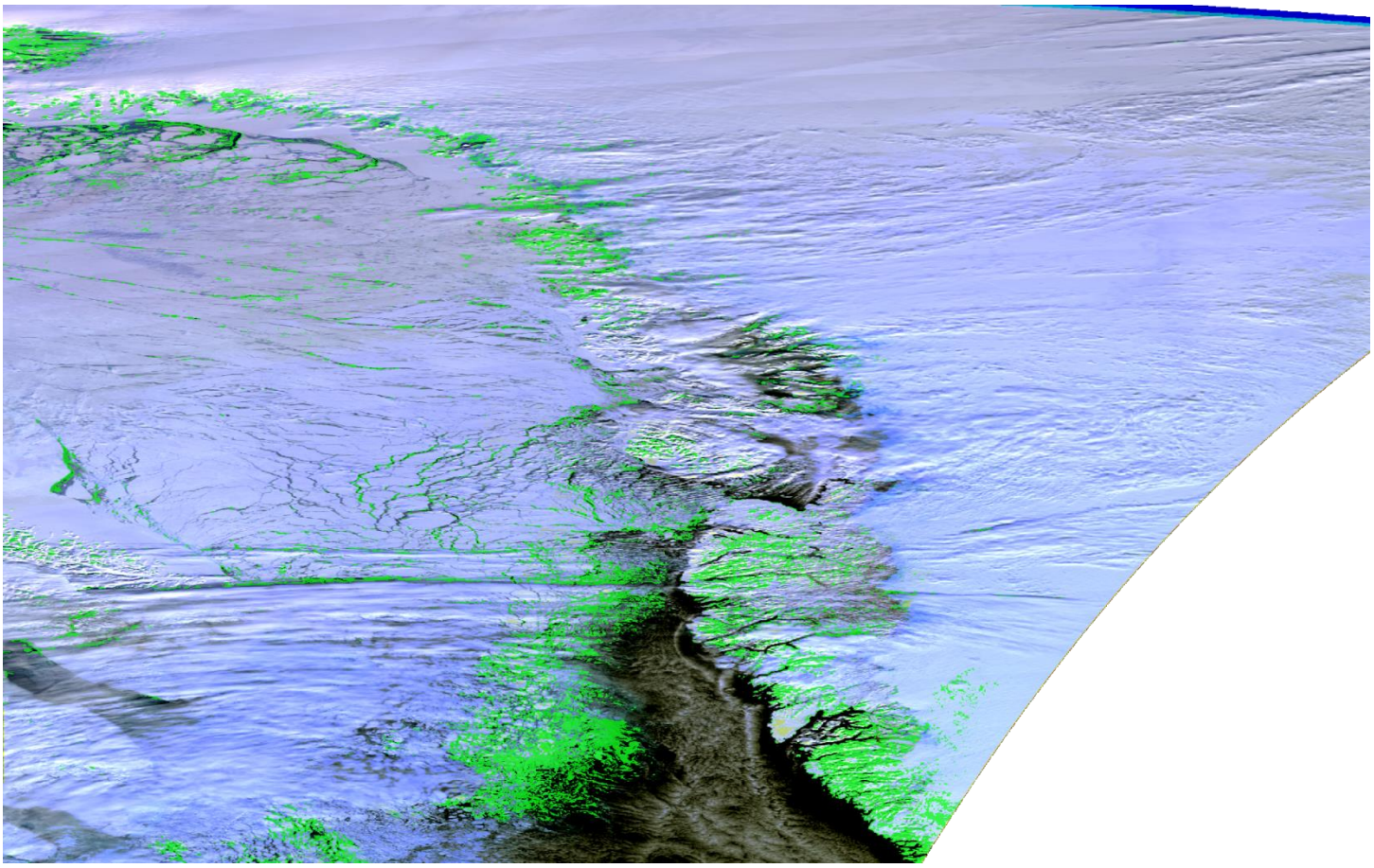
6,5



27. The same Fragment. Not all of clear sky ice pixels are marked.



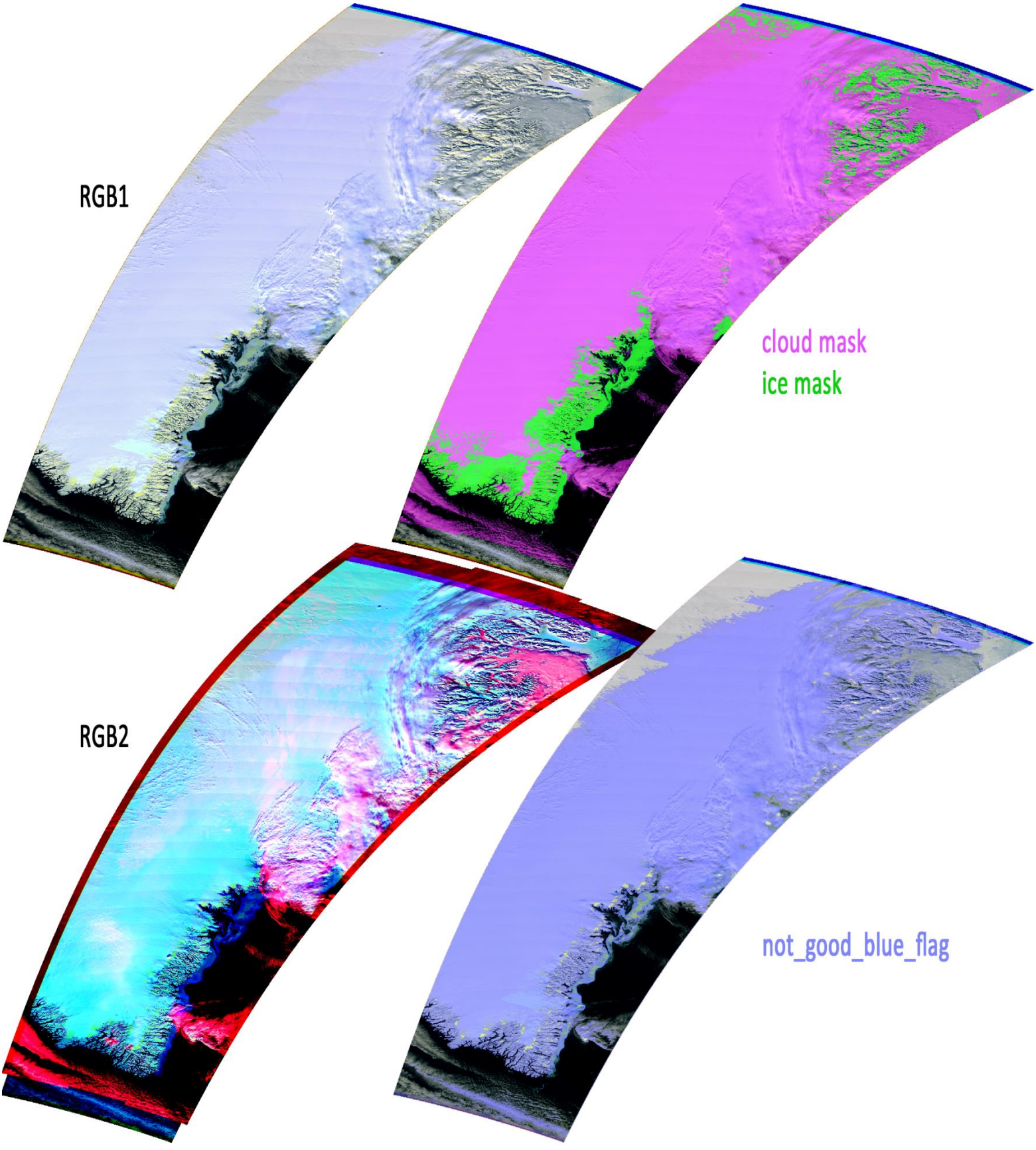
↑ RGB2



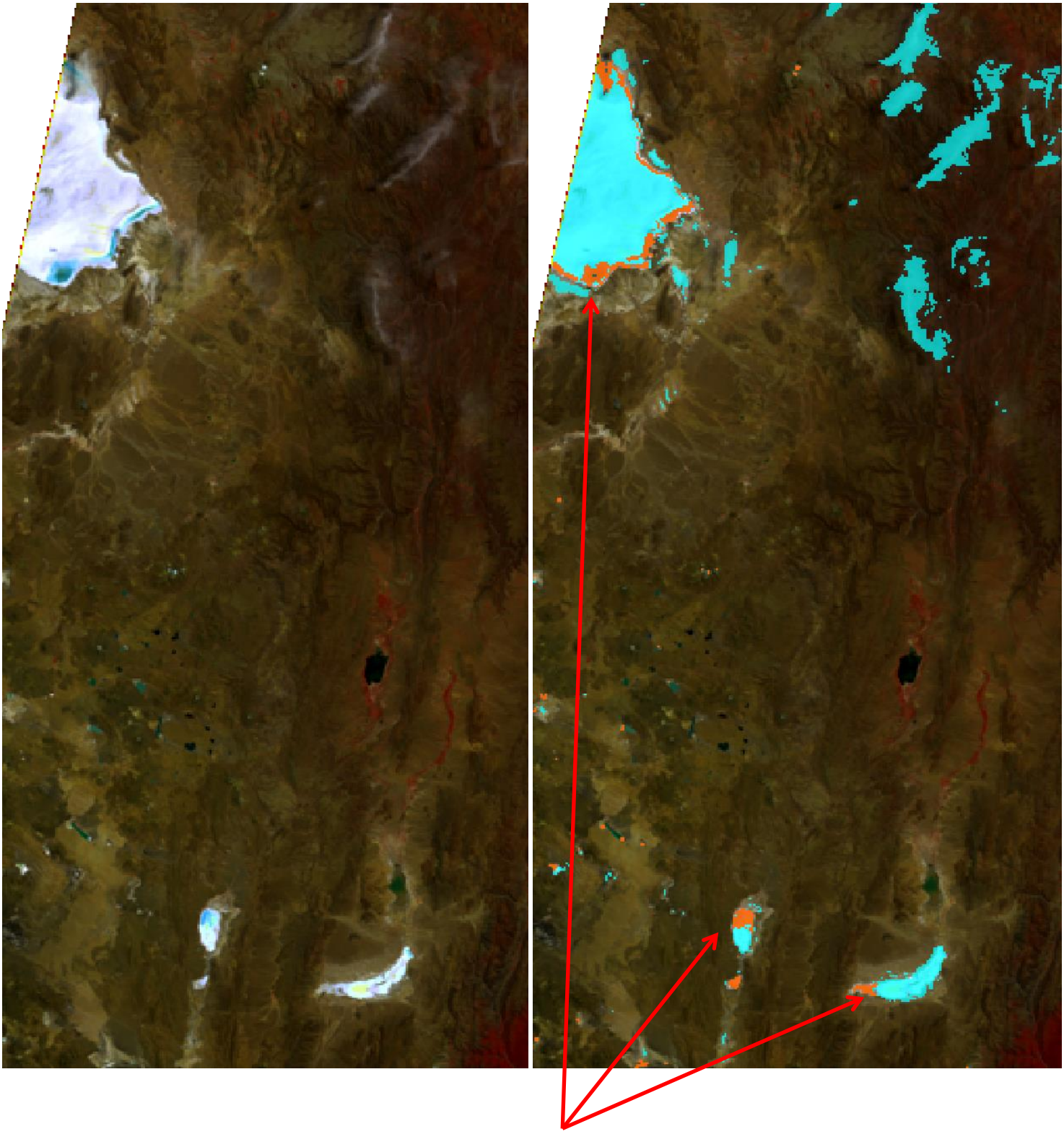
↑ RGB1 + Ice mask

28. PROBAV_L2A_20140321_144902_2_1KM_V103 (East Greenland)

A lot of land ice and sea ice pixels are wrongly marked as cloudy. The "not good blue" flag probably affects the making the right decision.

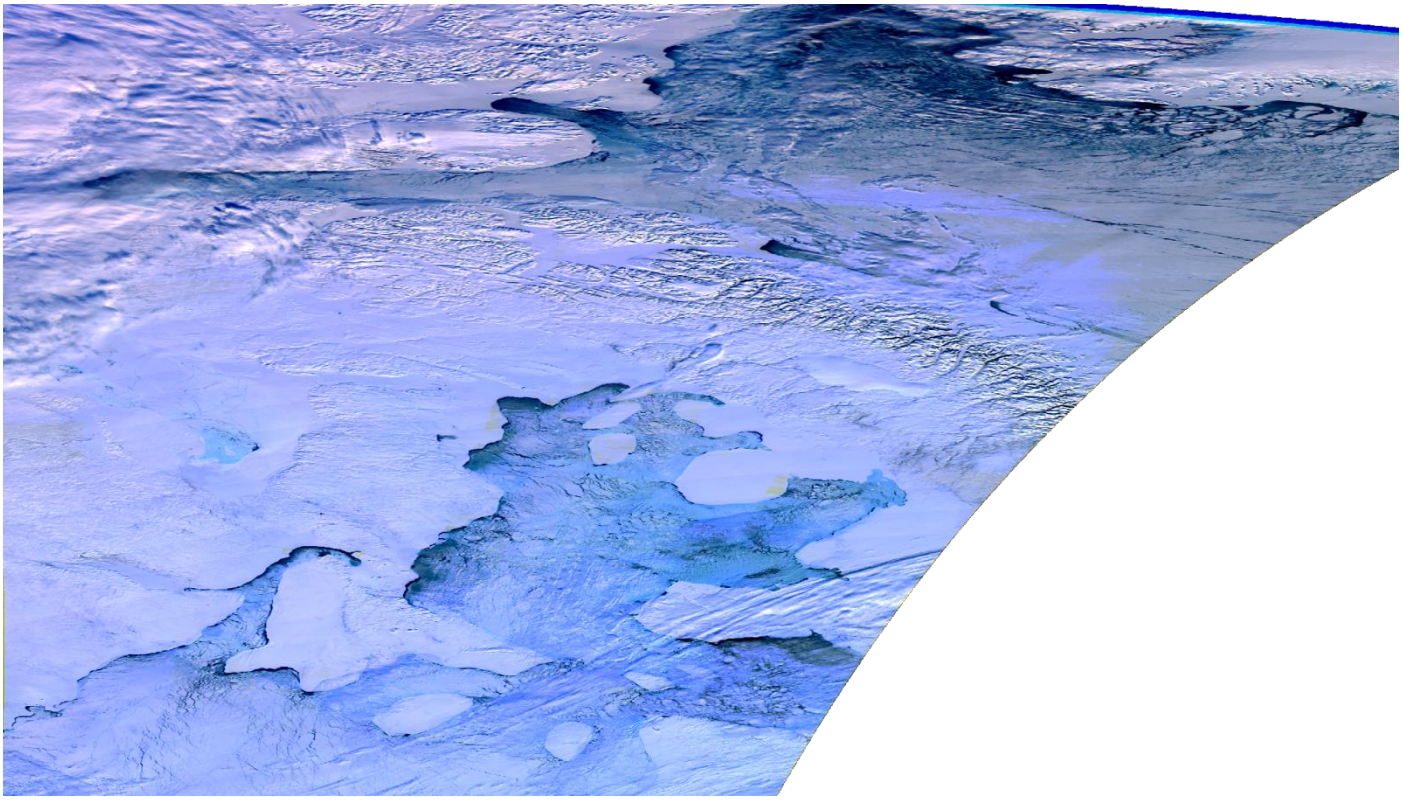


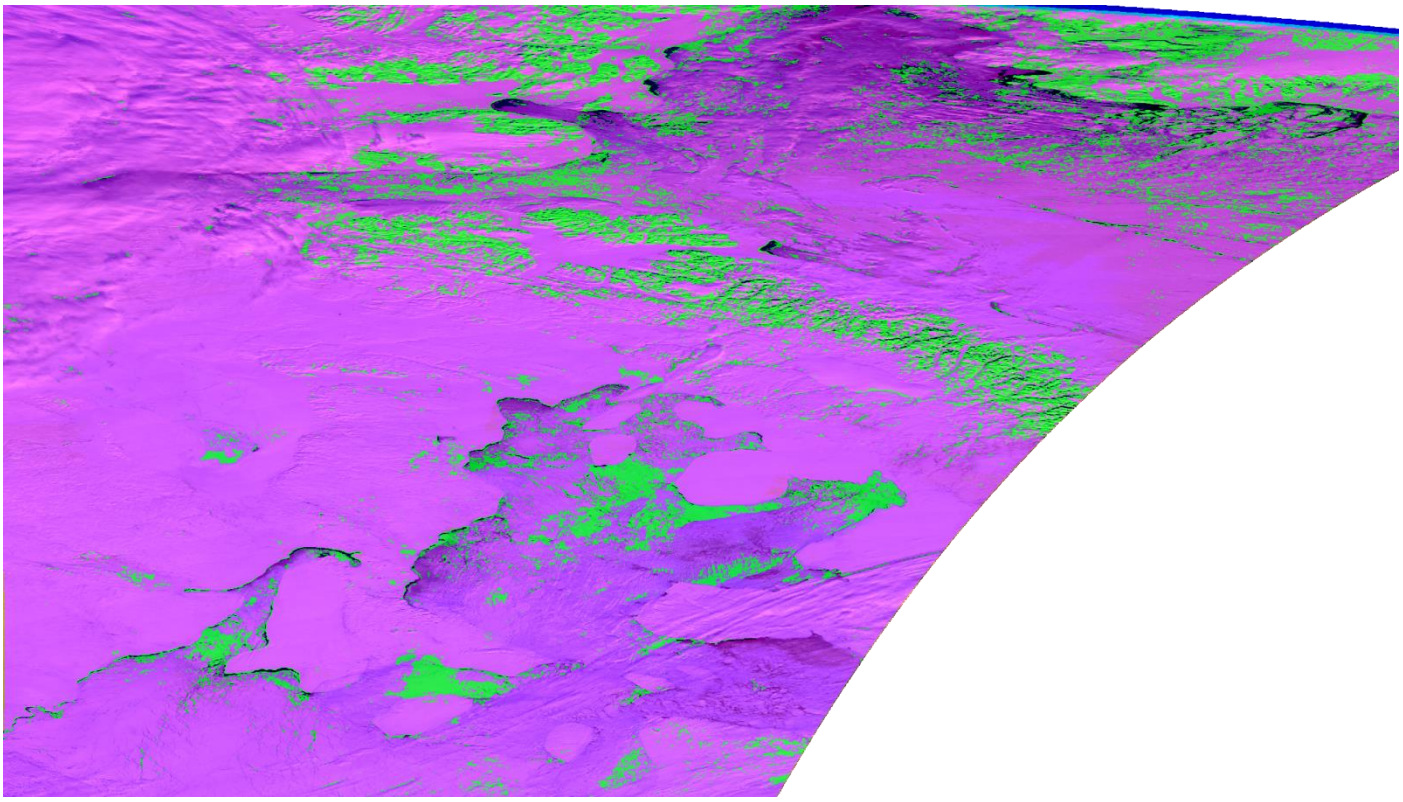
29. PROBAV_L2A_20140321_150637_1_1KM_V103 (Bolivia, Salar de Uyuni)
Cloud-free salt lake pixels are incorrectly marked as cloudy or icy.



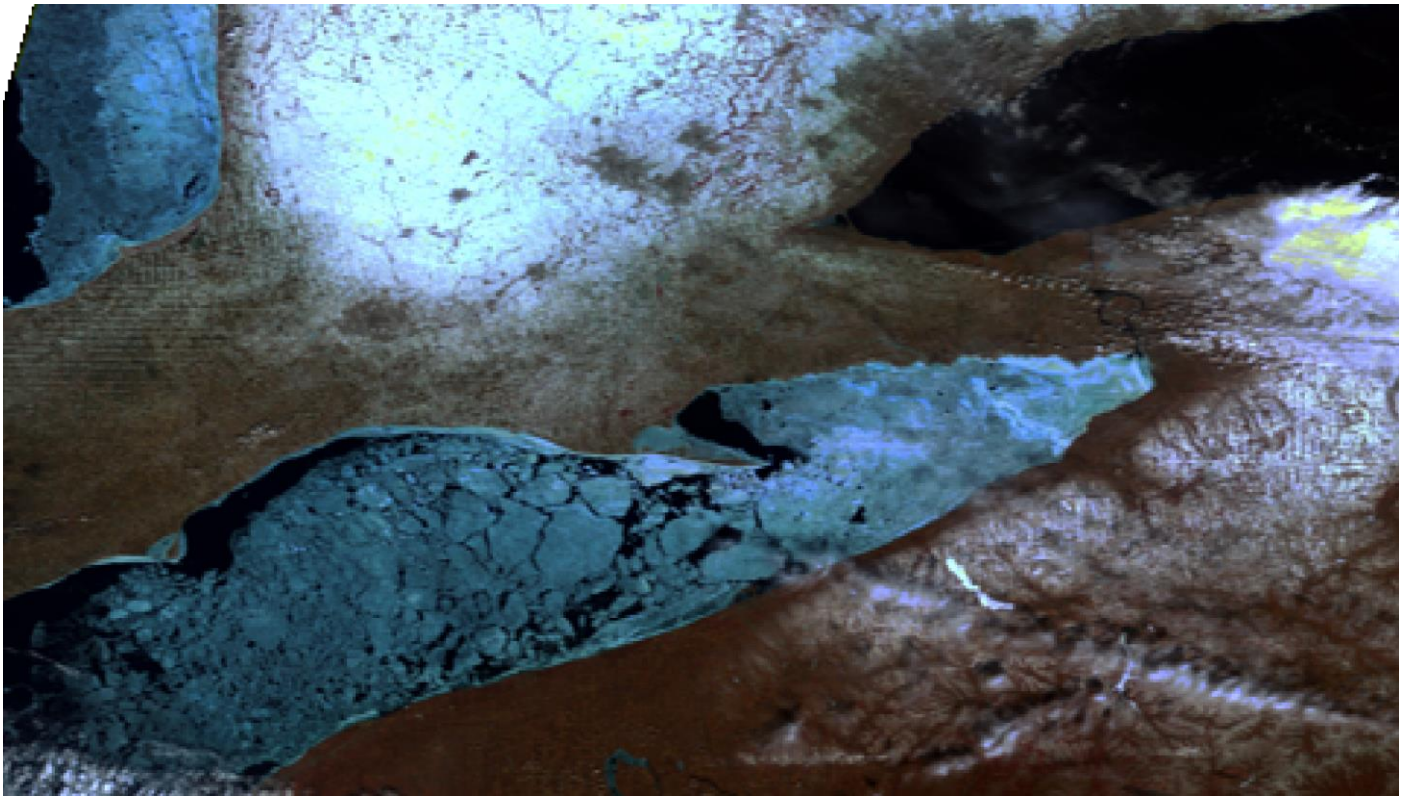
30. PROBAV_L2A_20140321_162957_3_1KM_V103 (Hudson Bay)

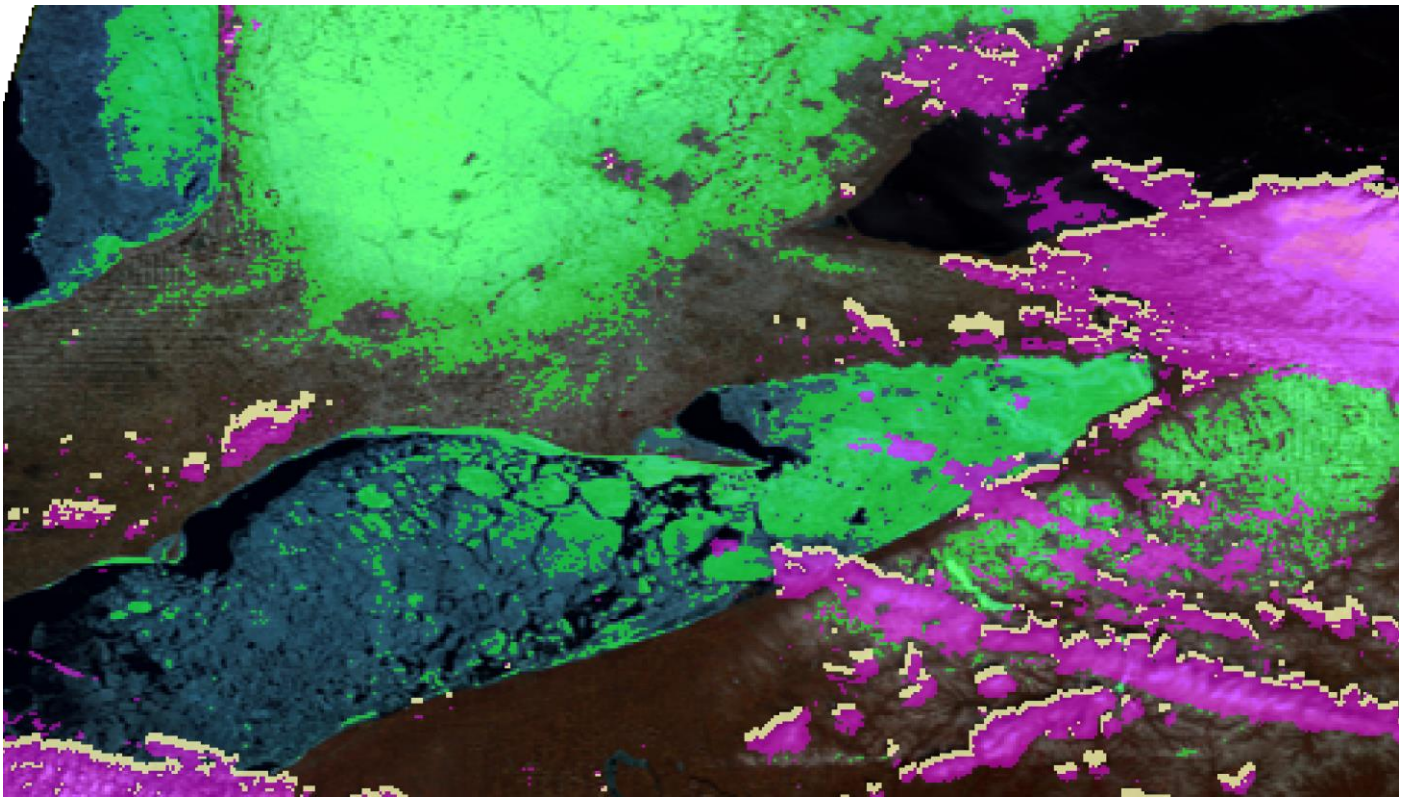
A lot of clear sky land ice and sea ice pixels are wrongly marked as cloudy.



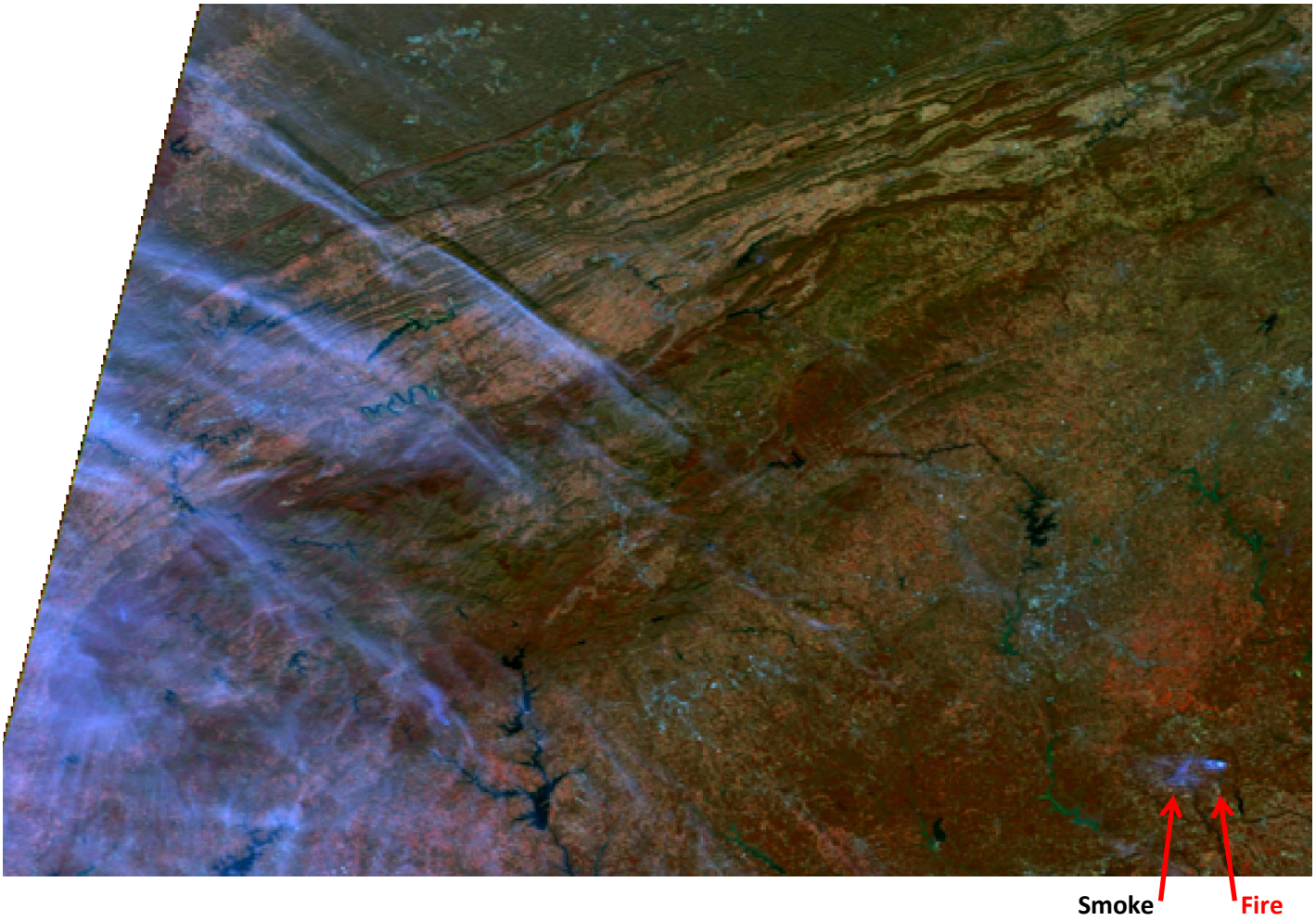


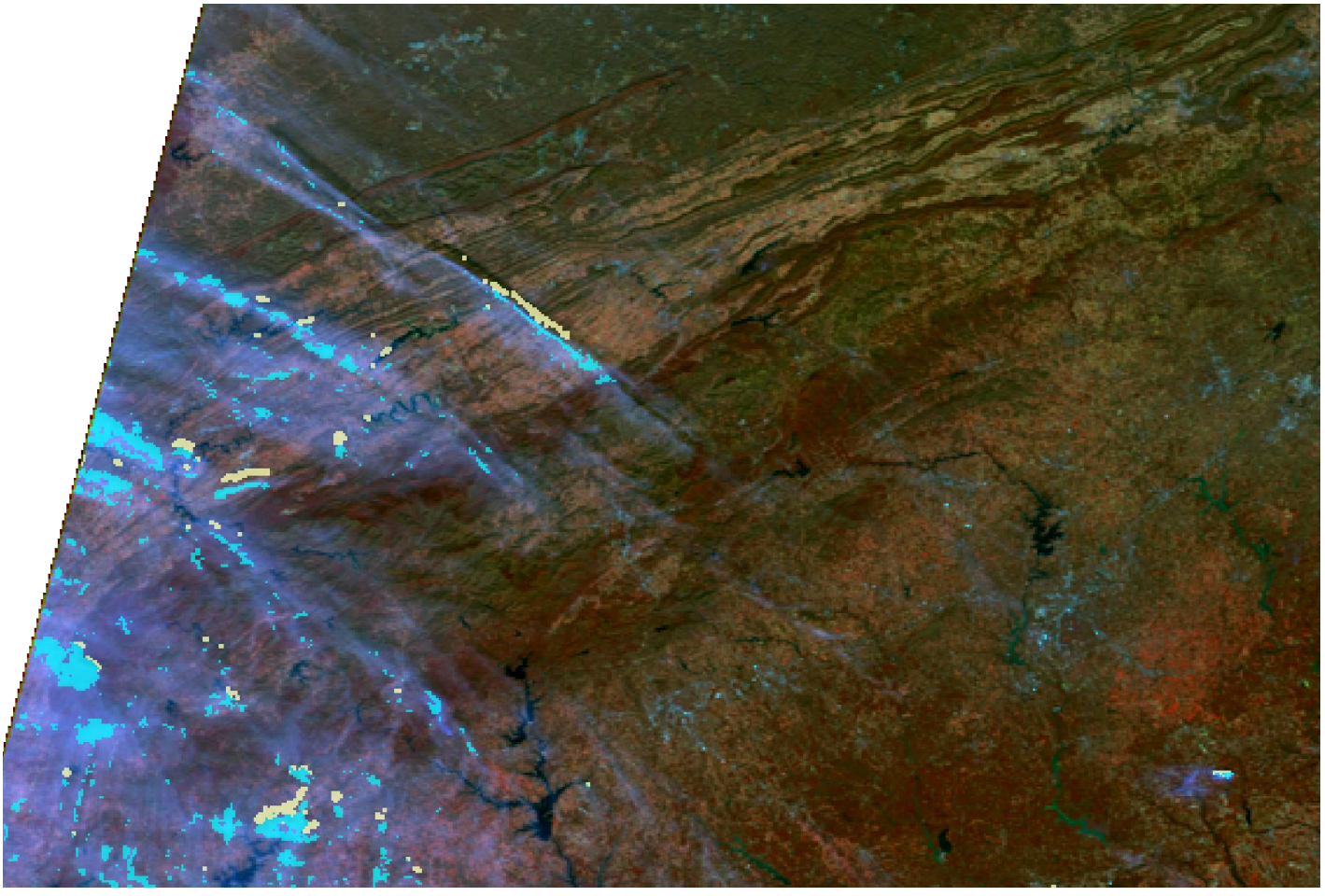
31. PROBAV_L2A_20140321_163018_2_1KM_V103 (In the Great Lakes area)
Some spatially mixed pixels are not recognized.
A lot of clear sky sea dark wet ice pixels are not recognized.





32. The same Fragment (America Midwest)
Many semi-transparent clouds are not recognized.

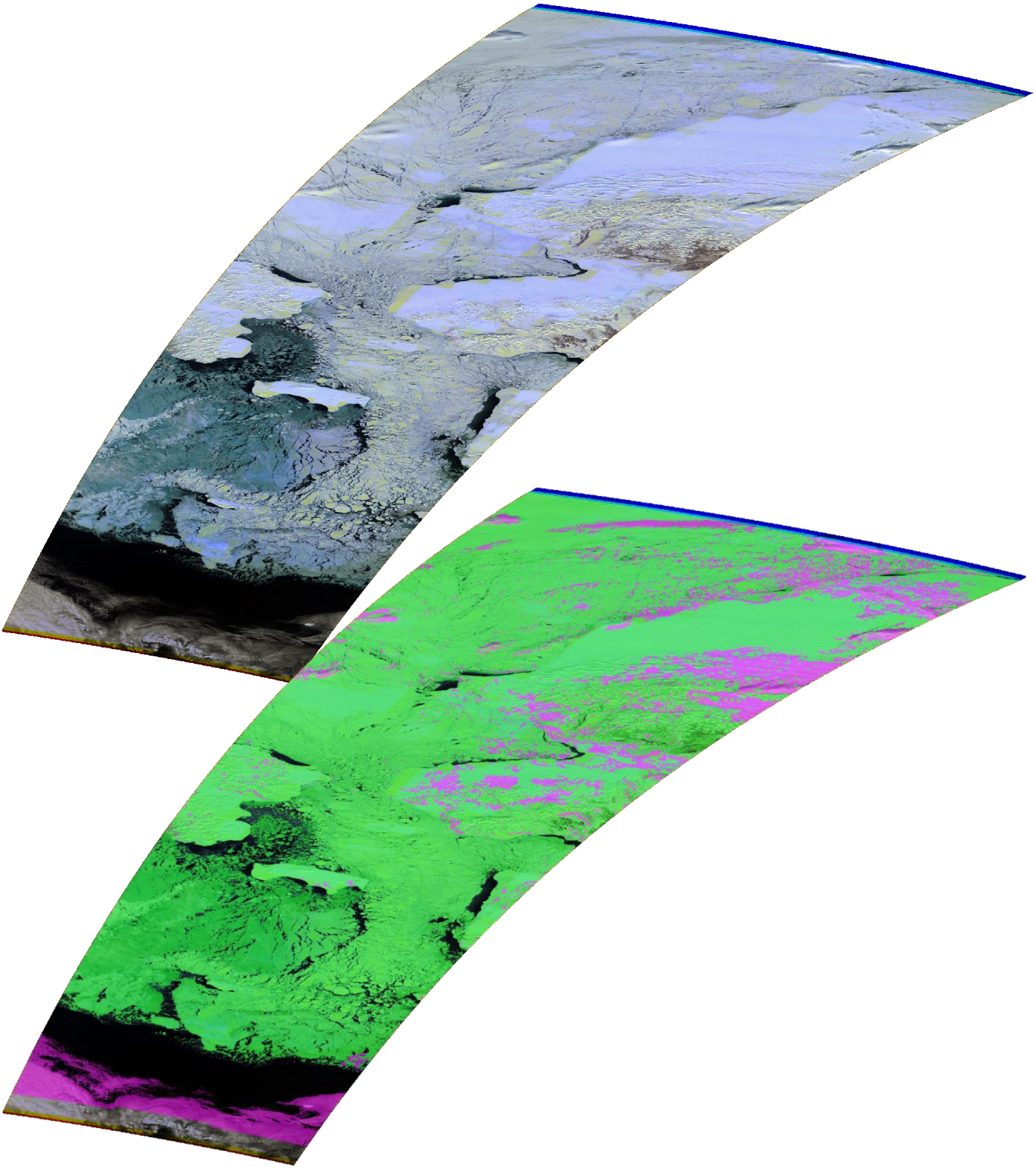




33. PROBAV_L2A_20140321_231600_2_1KM_V103 (Bering Sea, Chukchi Sea)

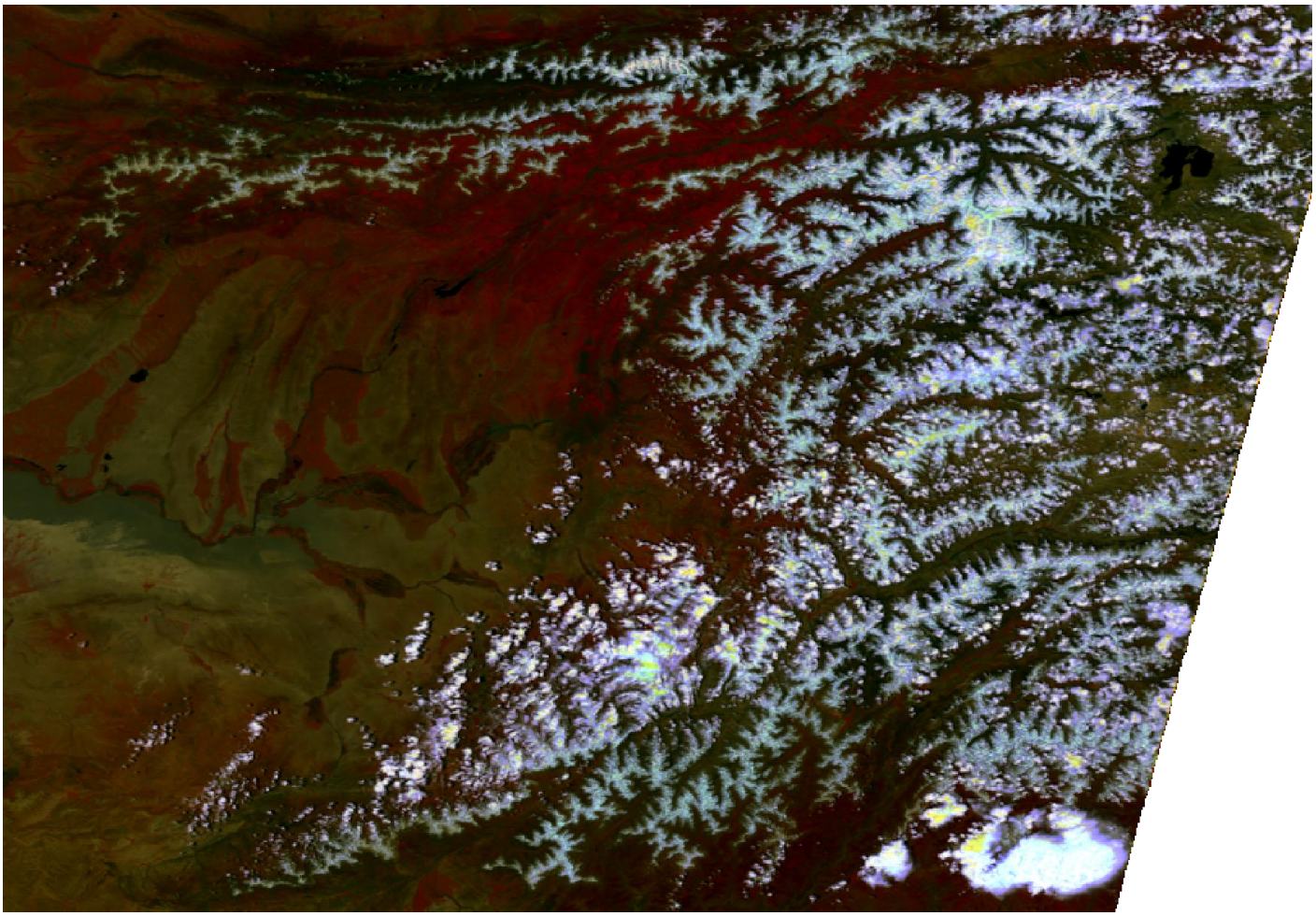
A good recognition of clear sky land ice and sea ice as well as separation of clouds.

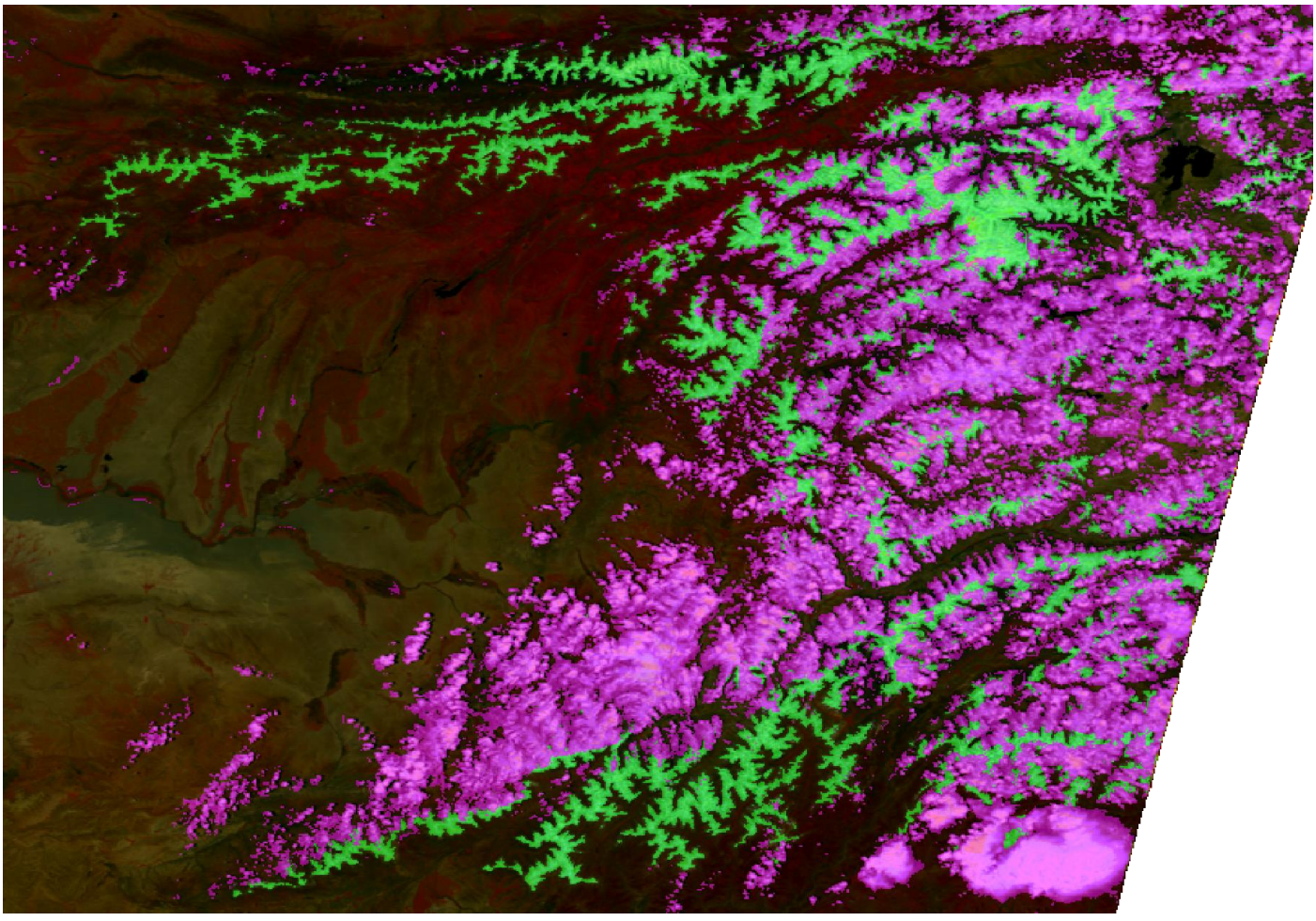
It seems to me that camera “2” works a little better in this sense. Although I can not prove it.



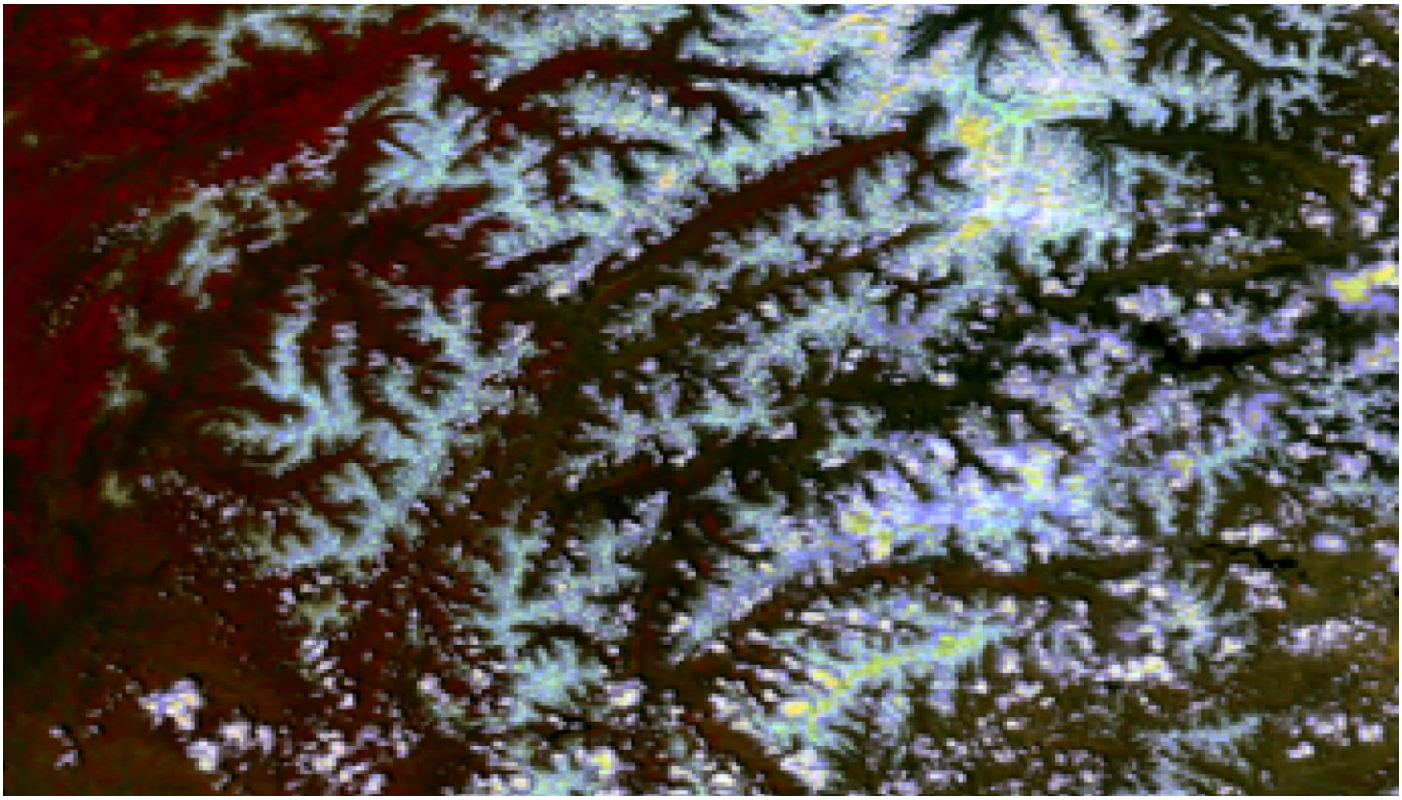
34. PROBAV_L2A_20140621_055928_3_1KM_V103 (Uzbekistan, Tadzhikistan)

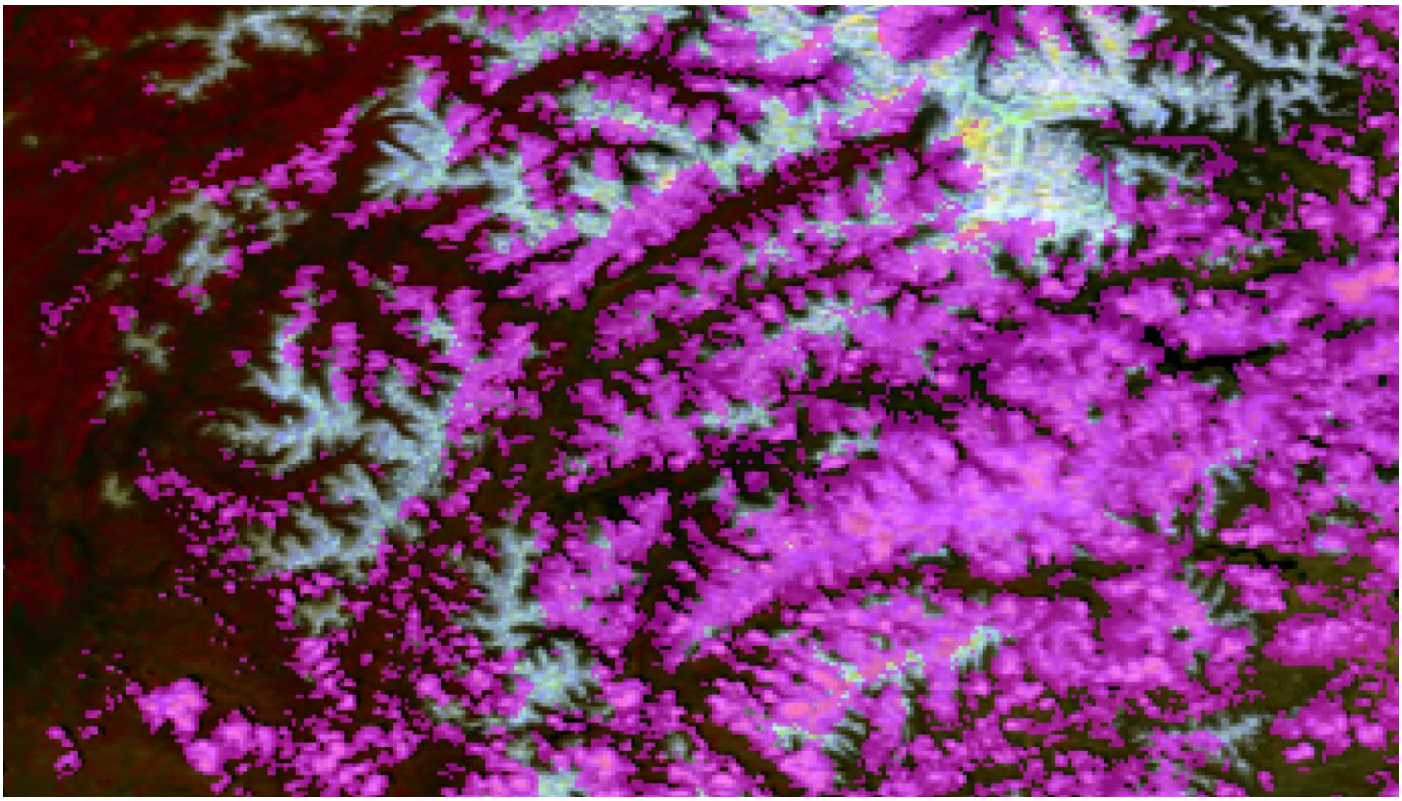
Here I am not sure about the correct application of masks.



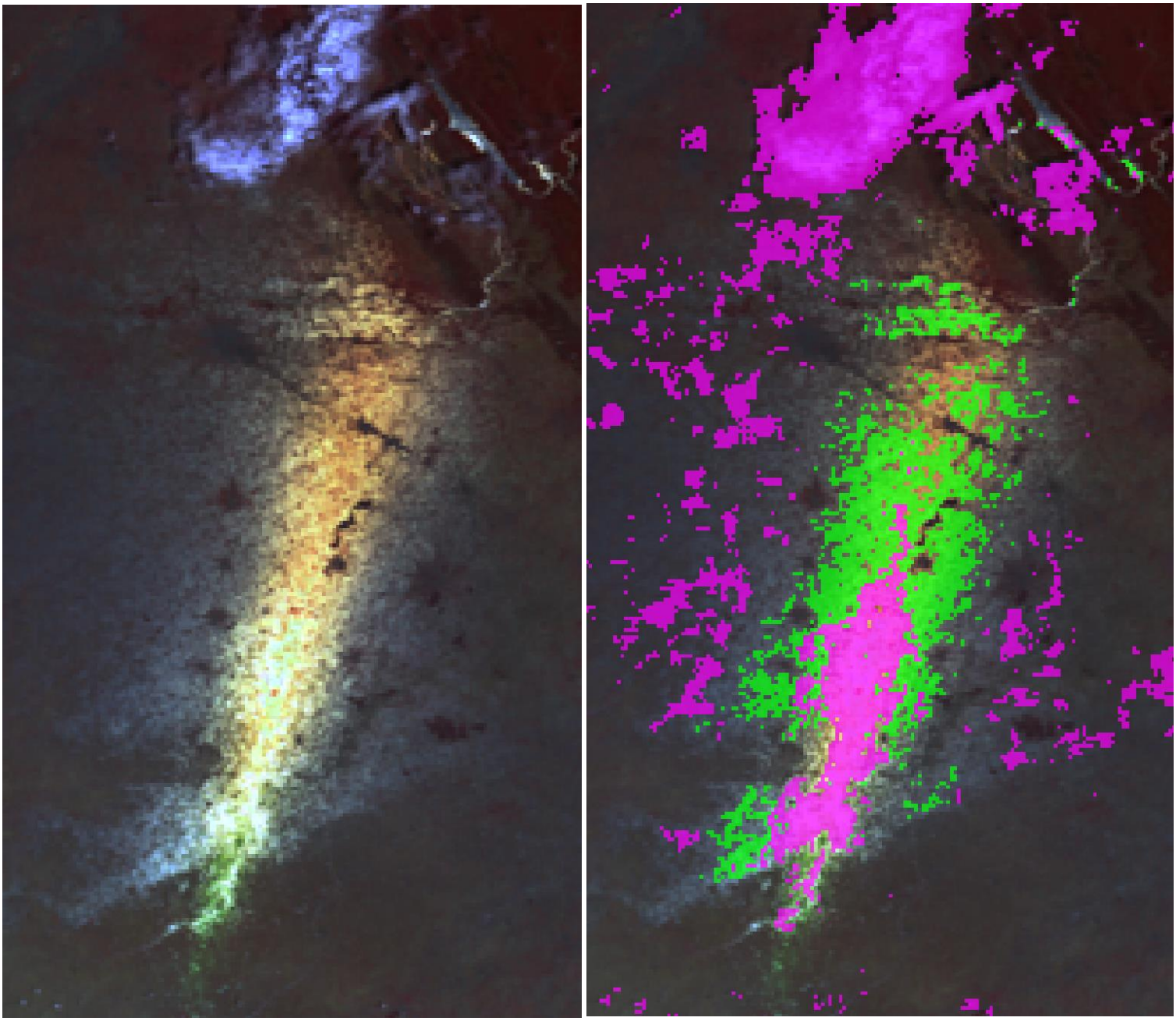


The same area zoomed.



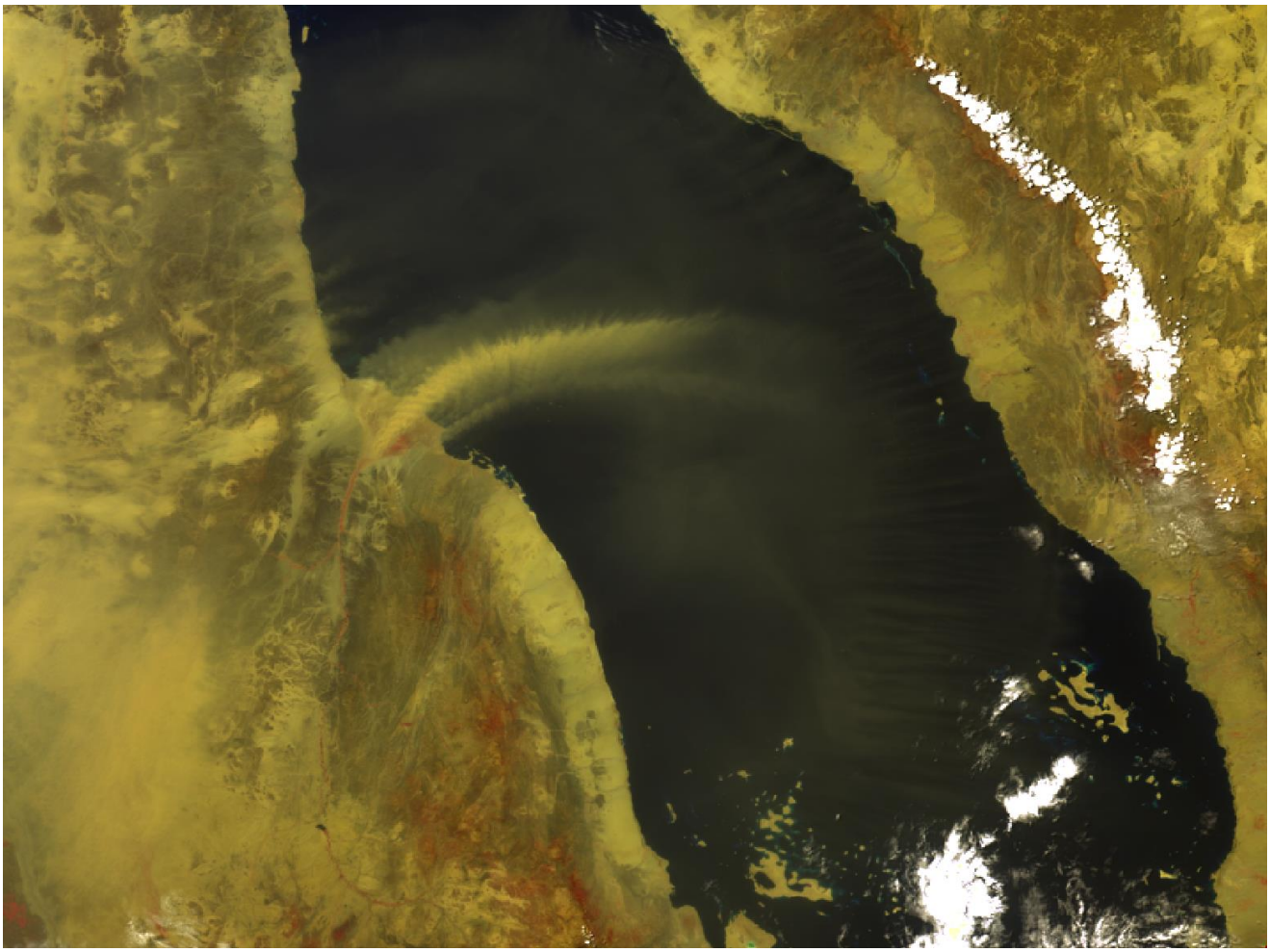


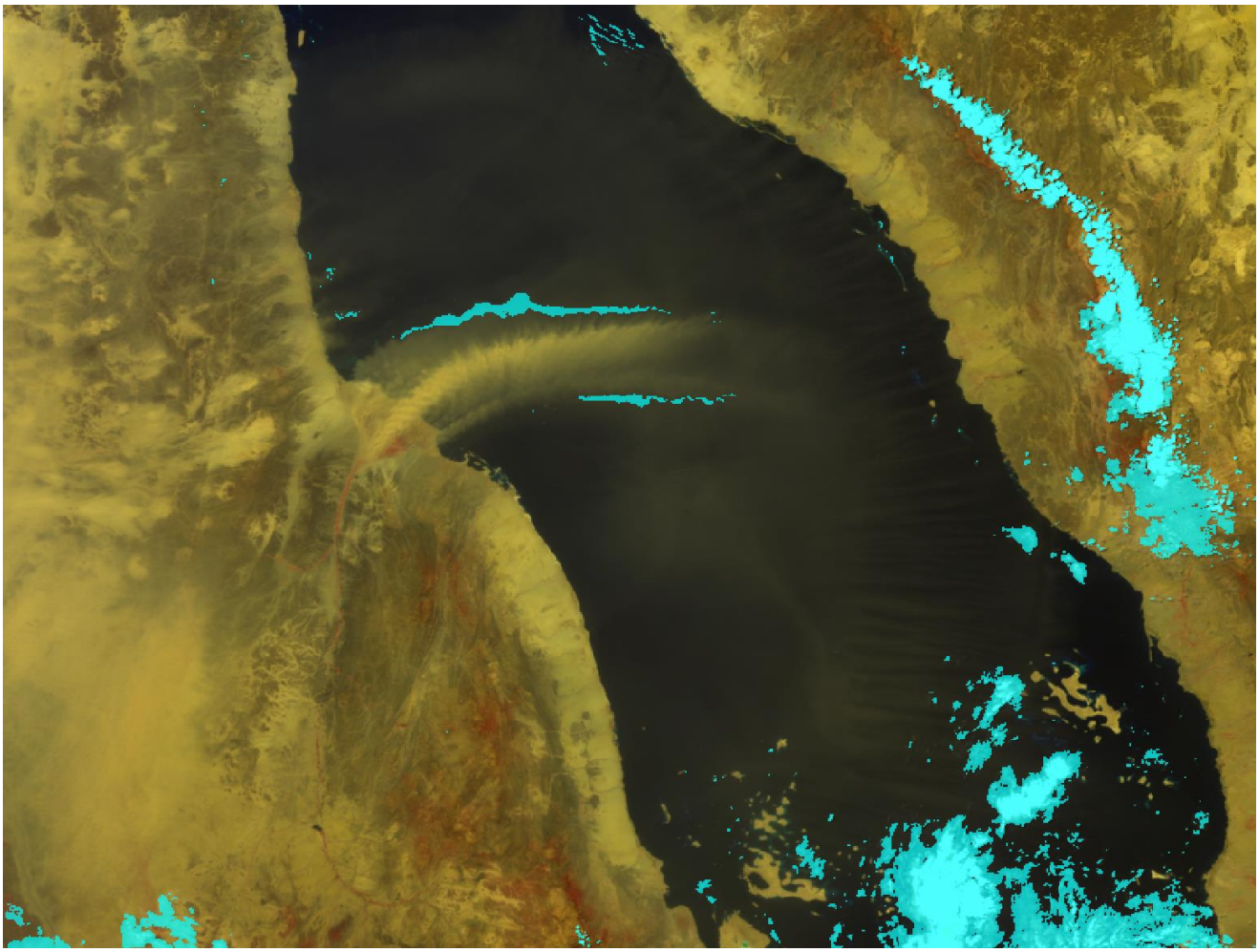
35. The same Fragment (North India, Sun glint on land)
Completely wrong masking of sun glint area.



36. PROBAV_L2A_20140621_074052_3_1KM_V103 (Caspian Sea)

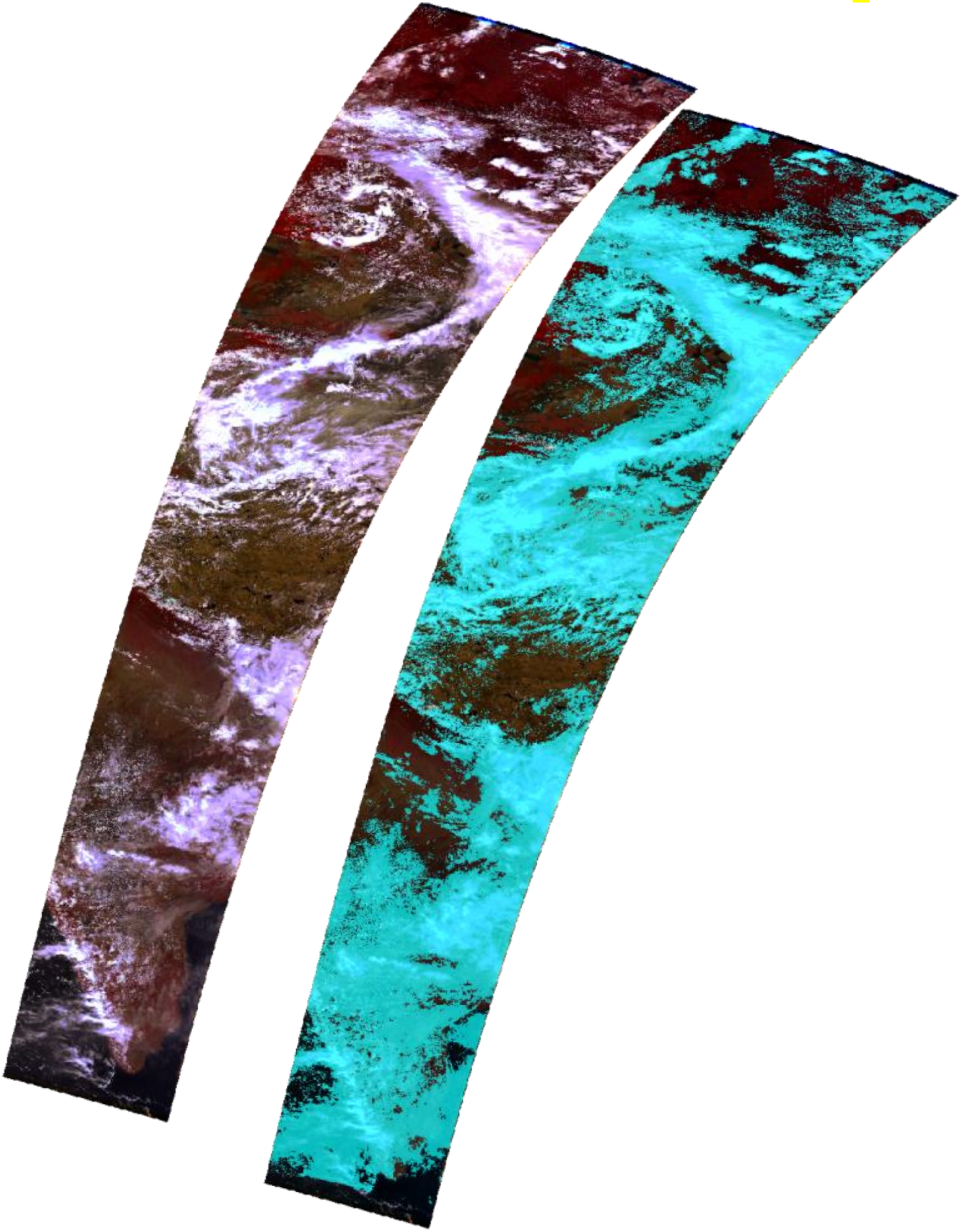
The aerosol is partially mistaken for cloud cover.



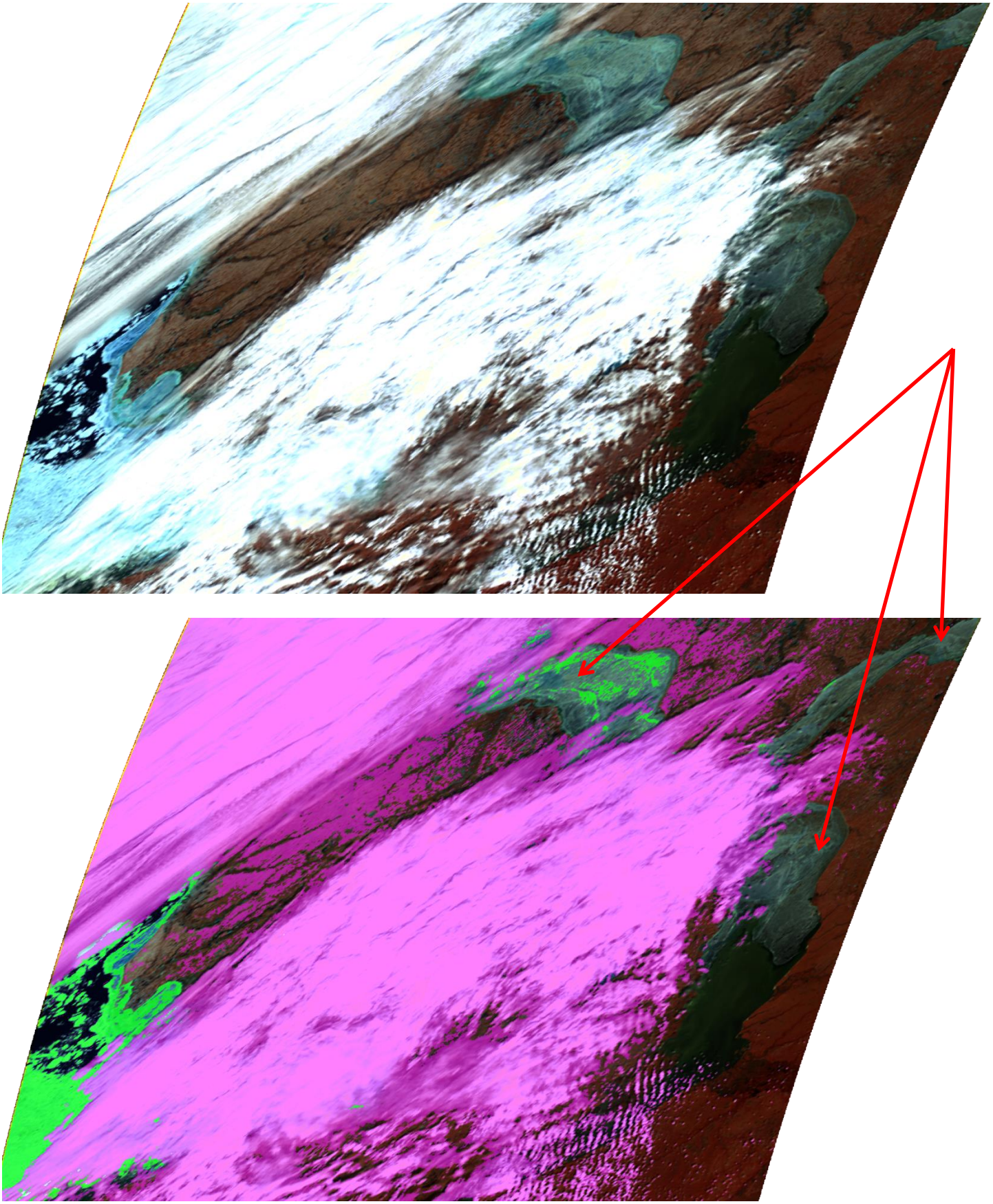


37. PROBAV_L2A_20140621_060411_1_1KM_V103 (In the top - West Siberia, Kazakhstan, in the bottom - India)

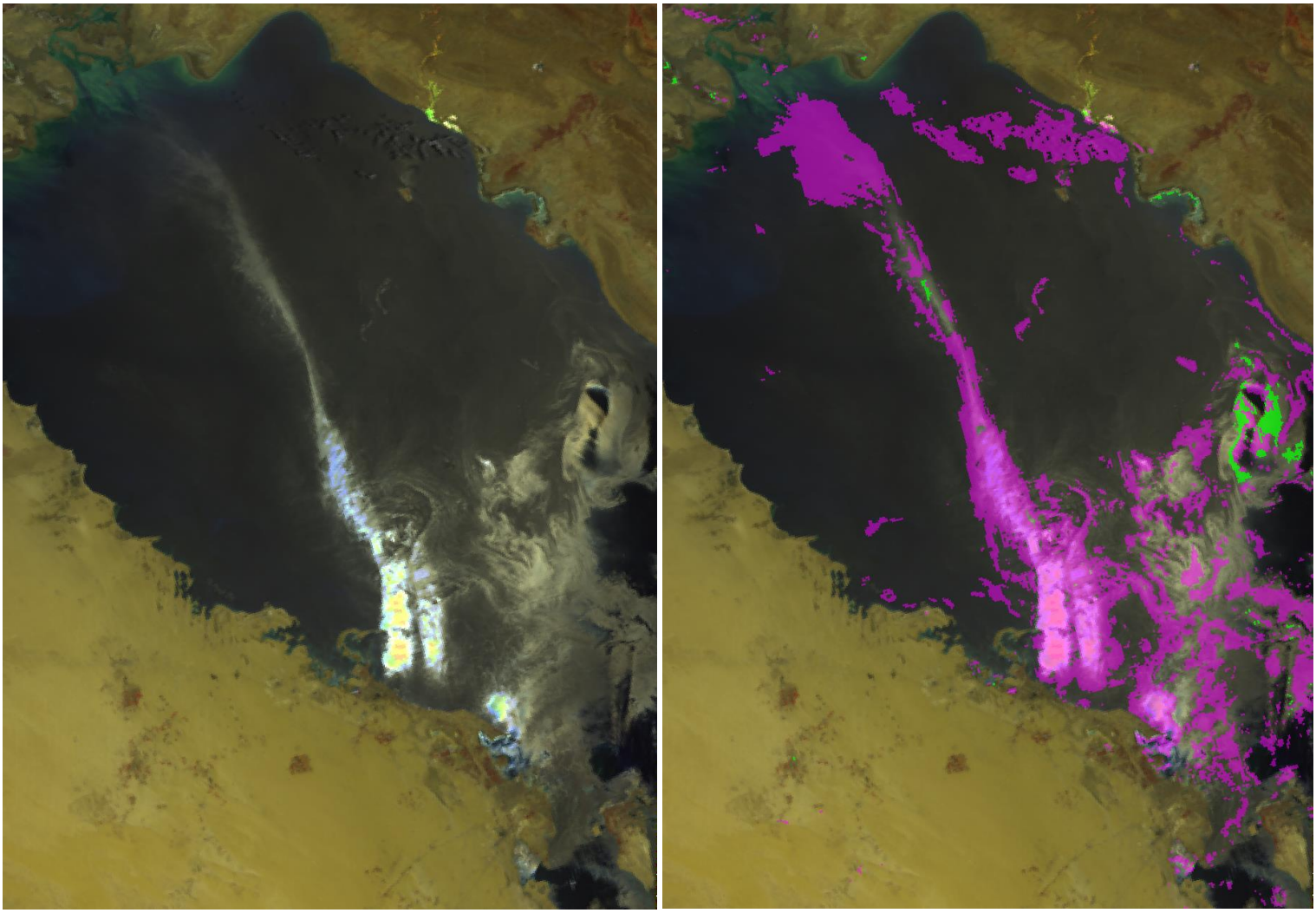
⊙ 9,0



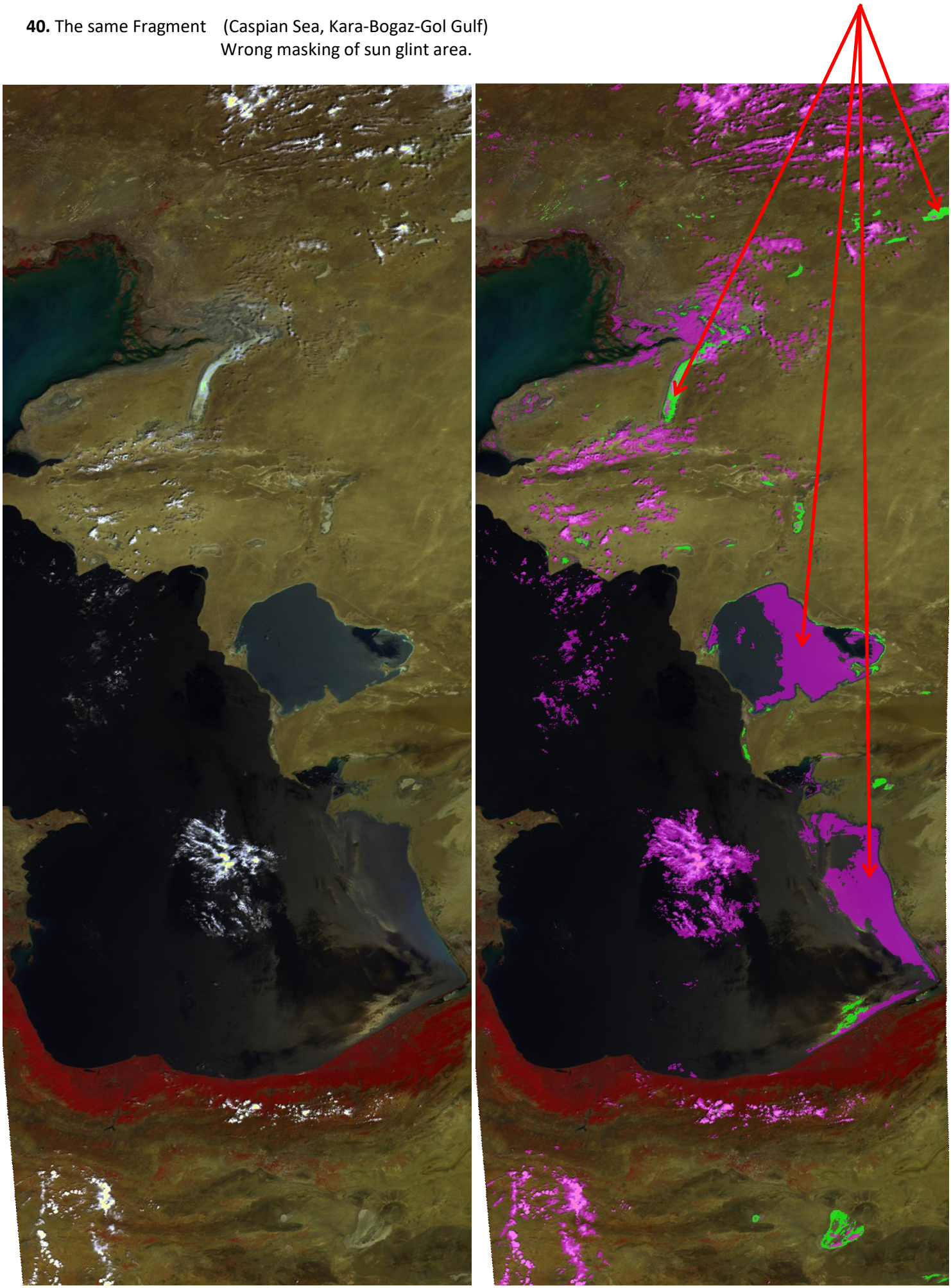
38. PROBAV_L2A_20140621_074105_2_1KM_V103 (Gulf of Ob)
Not all floating ice pixels are recognized.



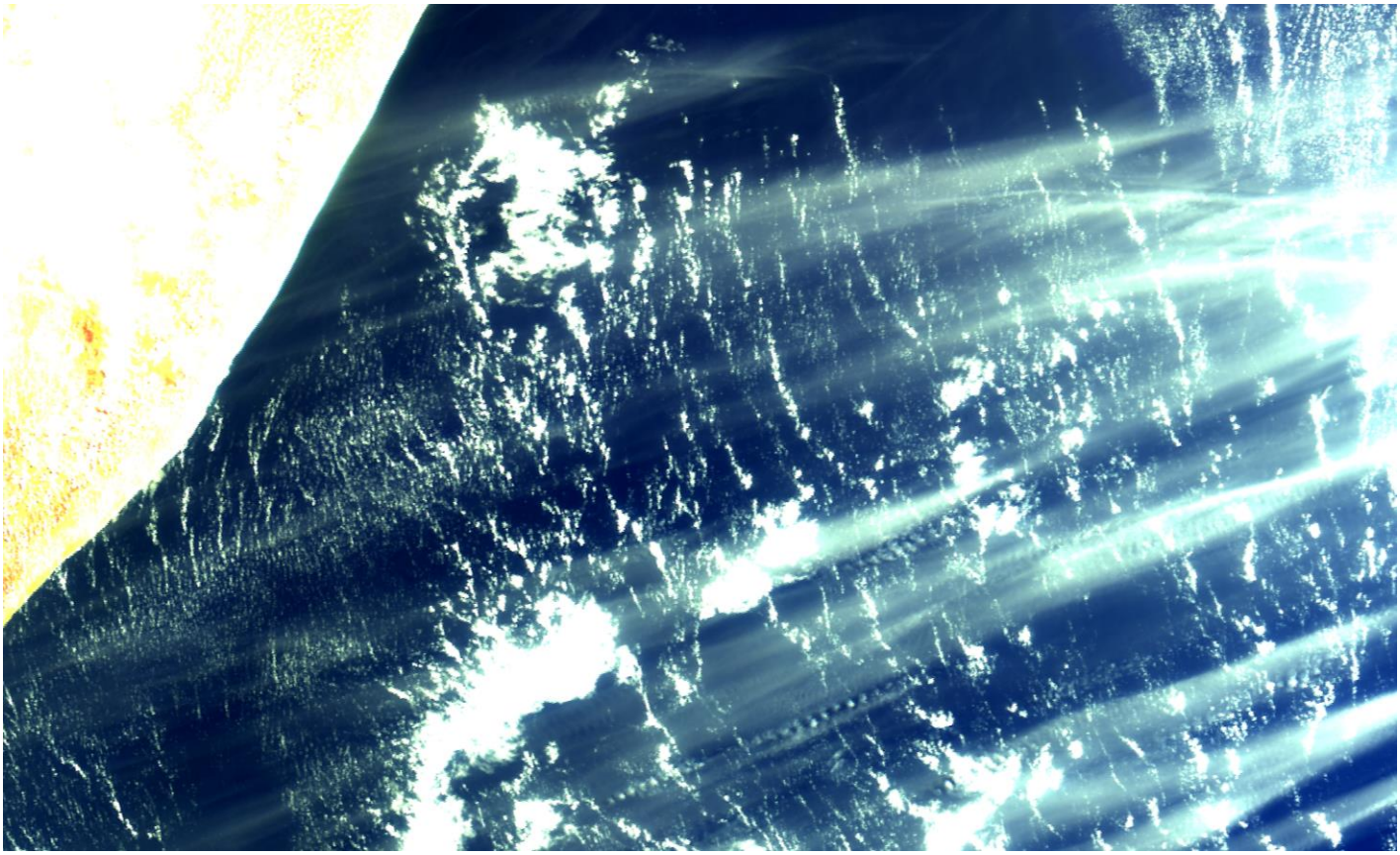
39. The same Fragment (Persian Gulf)
Wrong masking of sun glint area.

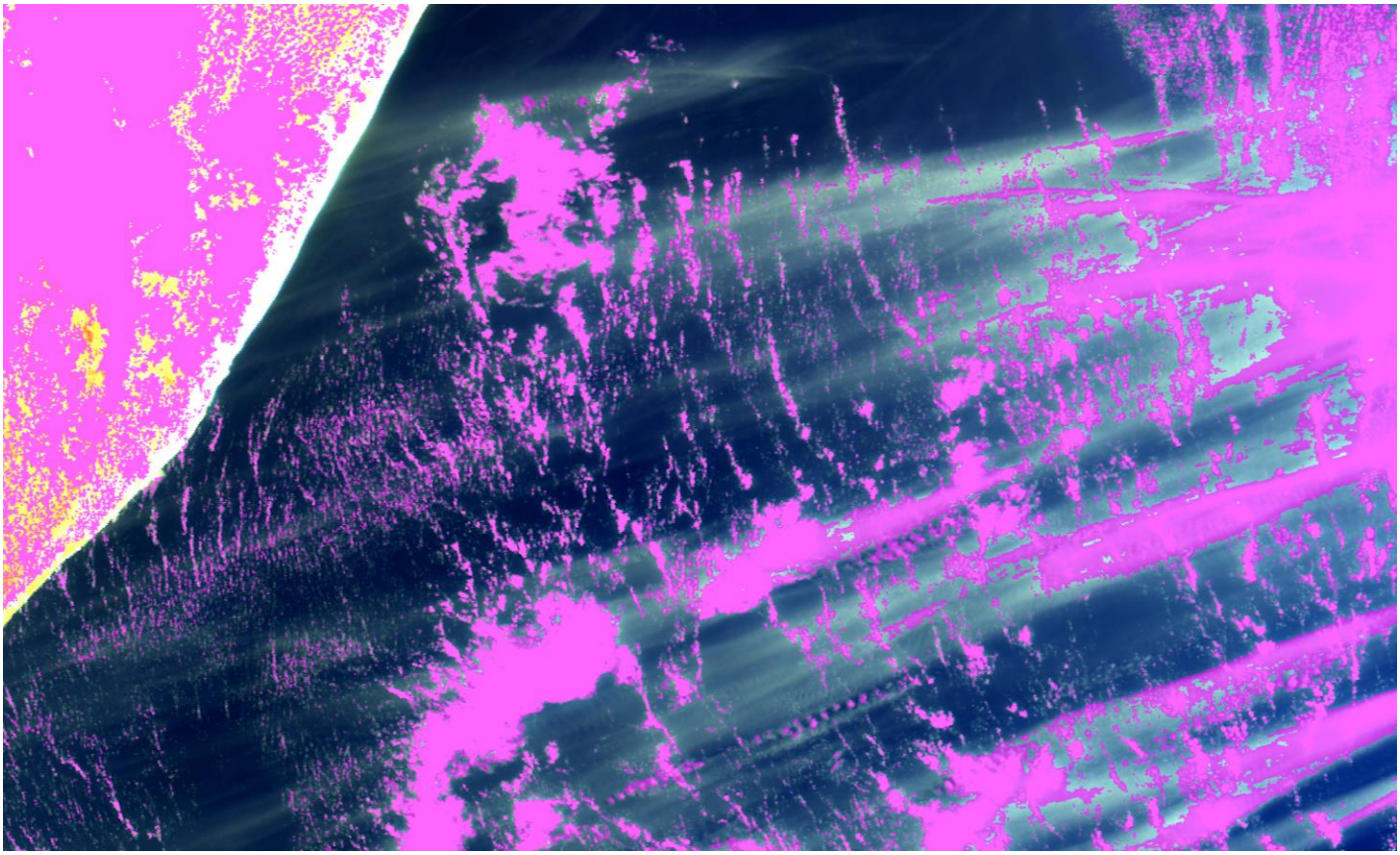


40. The same Fragment (Caspian Sea, Kara-Bogaz-Gol Gulf)
Wrong masking of sun glint area.



41. PROBAV_L2A_20140621_074527_1_1KM_V103 (West of Indian Ocean)
Semi-transparent clouds are not masked.

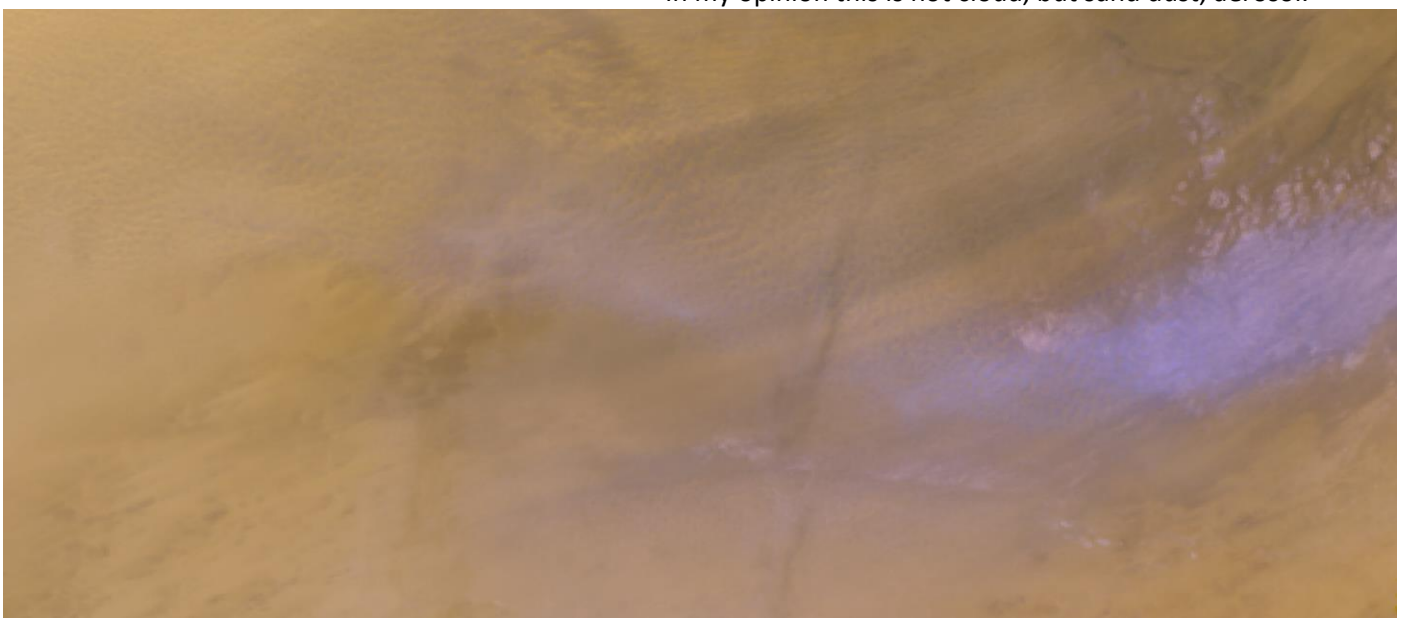


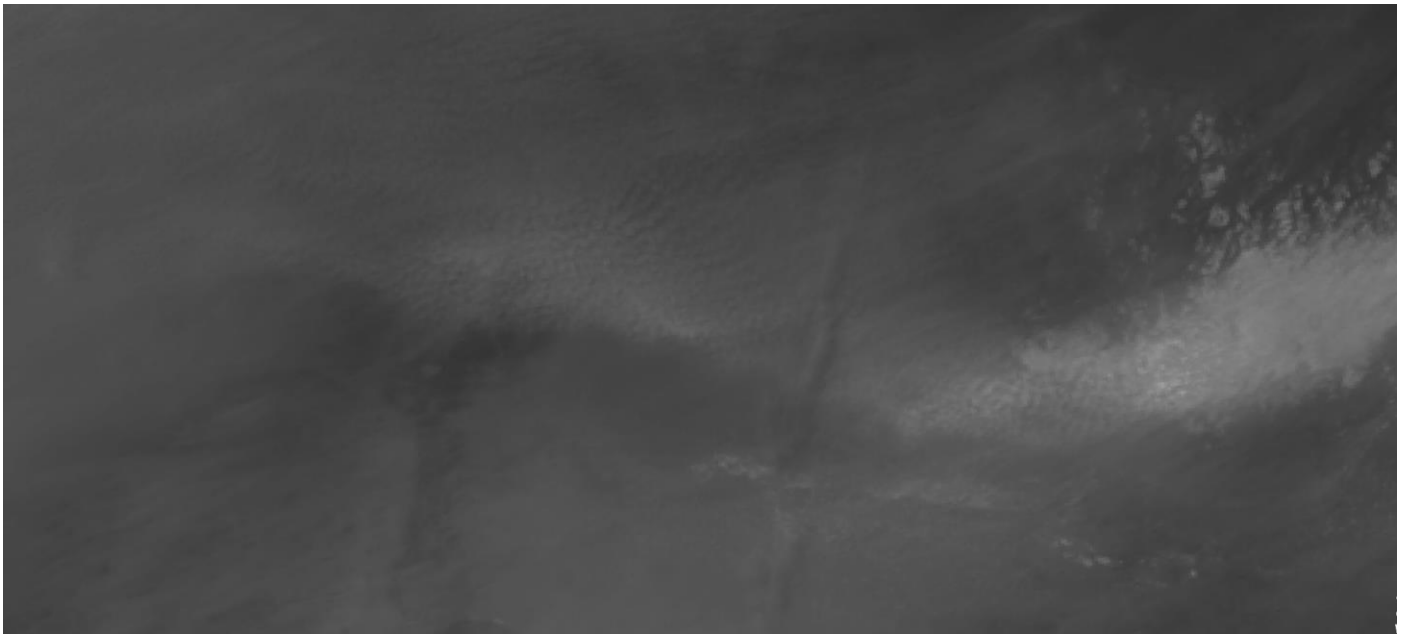


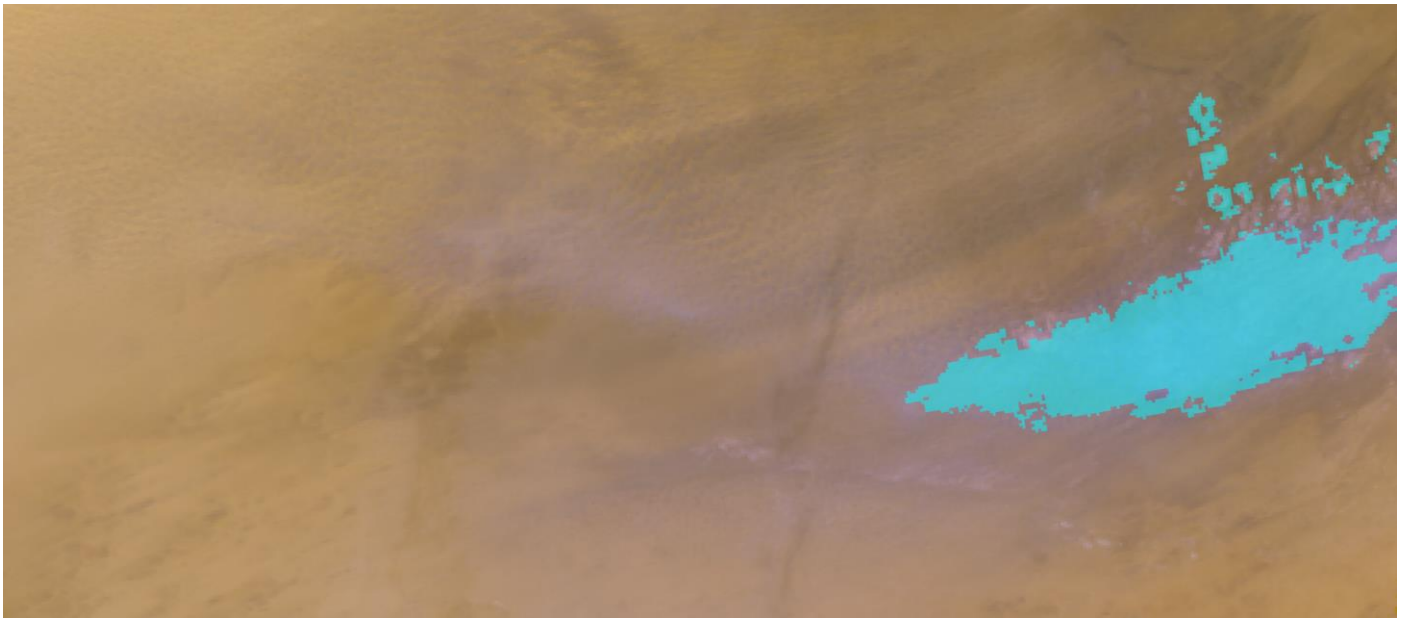
42. PROBAV_L2A_20140621_092203_3_1KM_V103 (Sahara)

RGB →
Toa_refl_blue →
Cloud mask

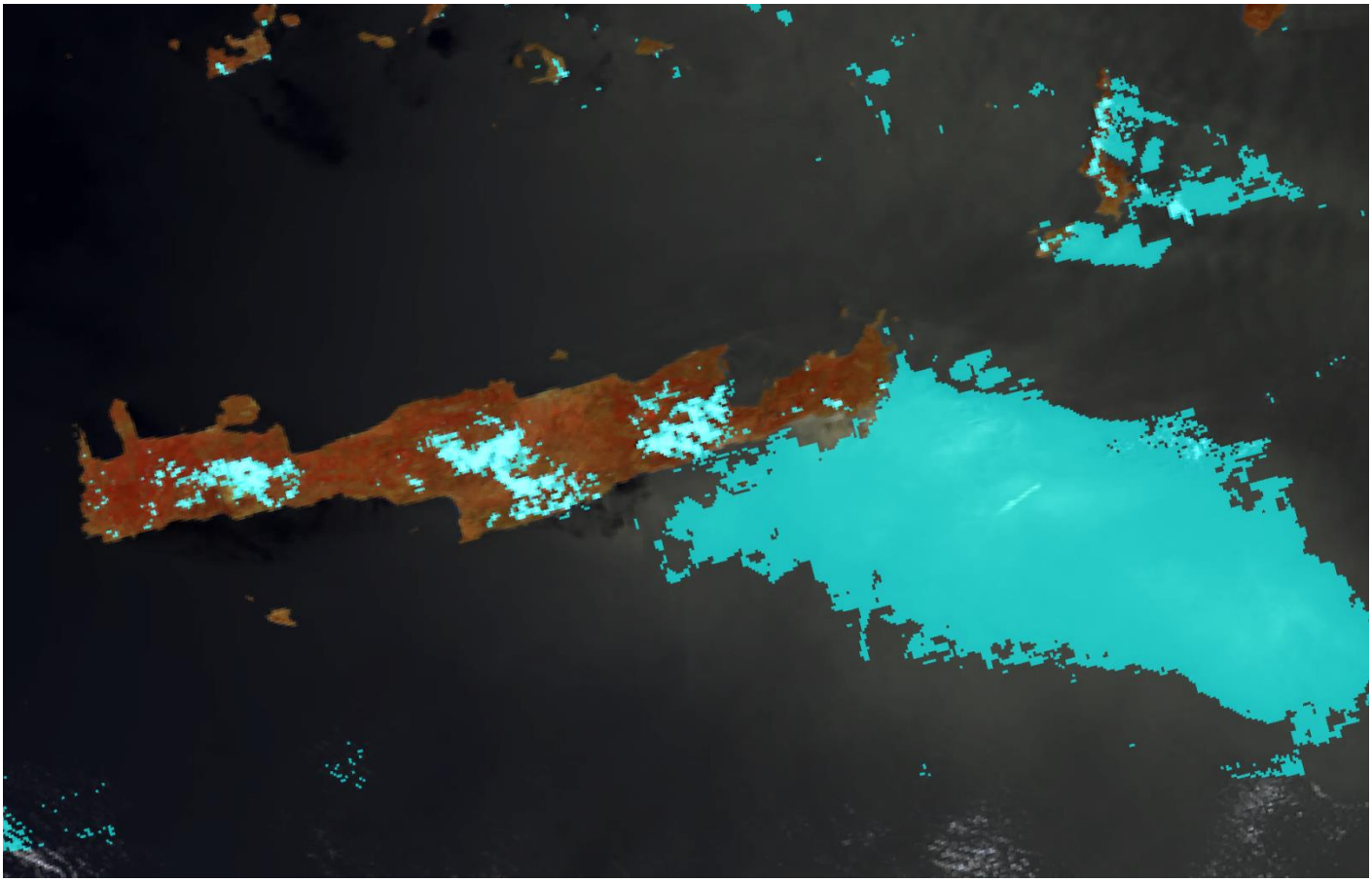
In my opinion this is not cloud, but sand dust, aerosol.



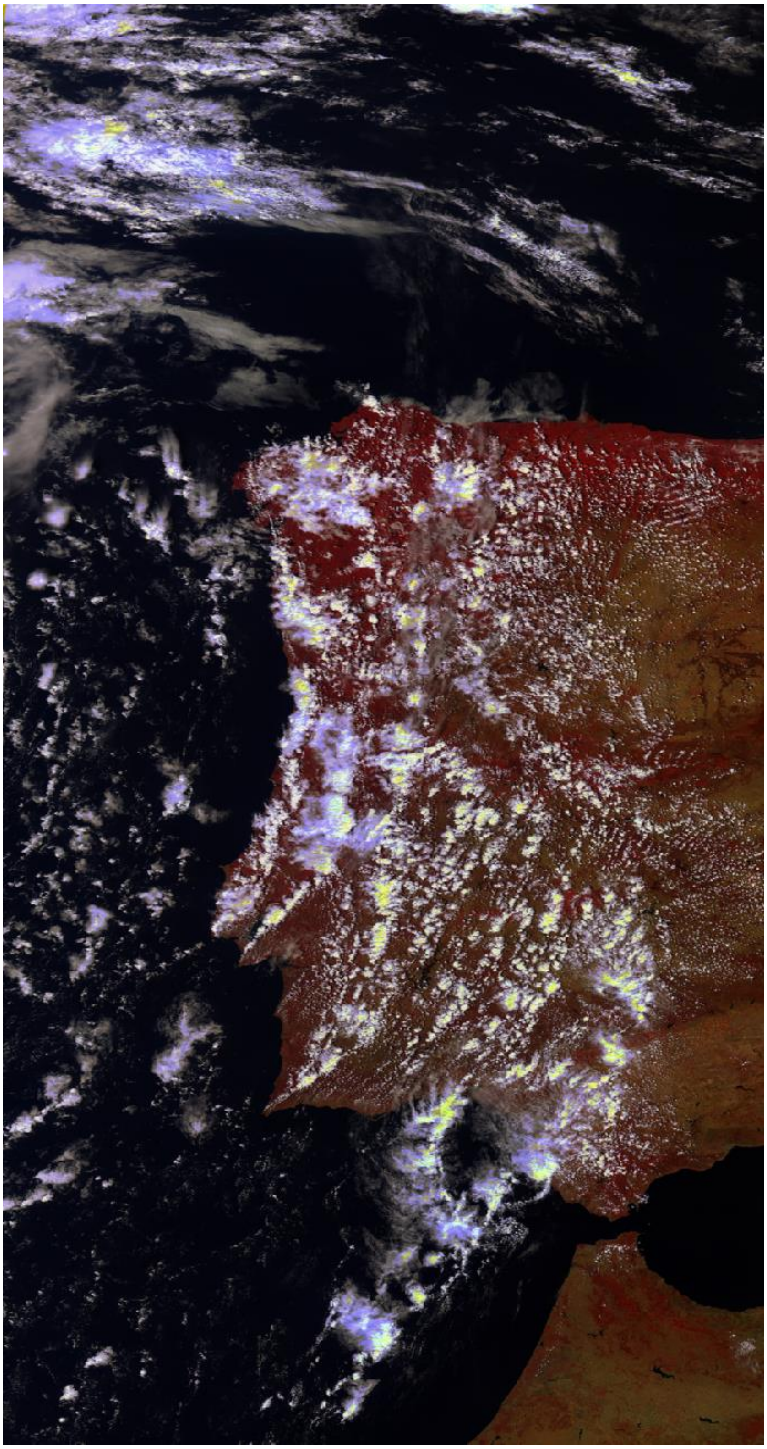


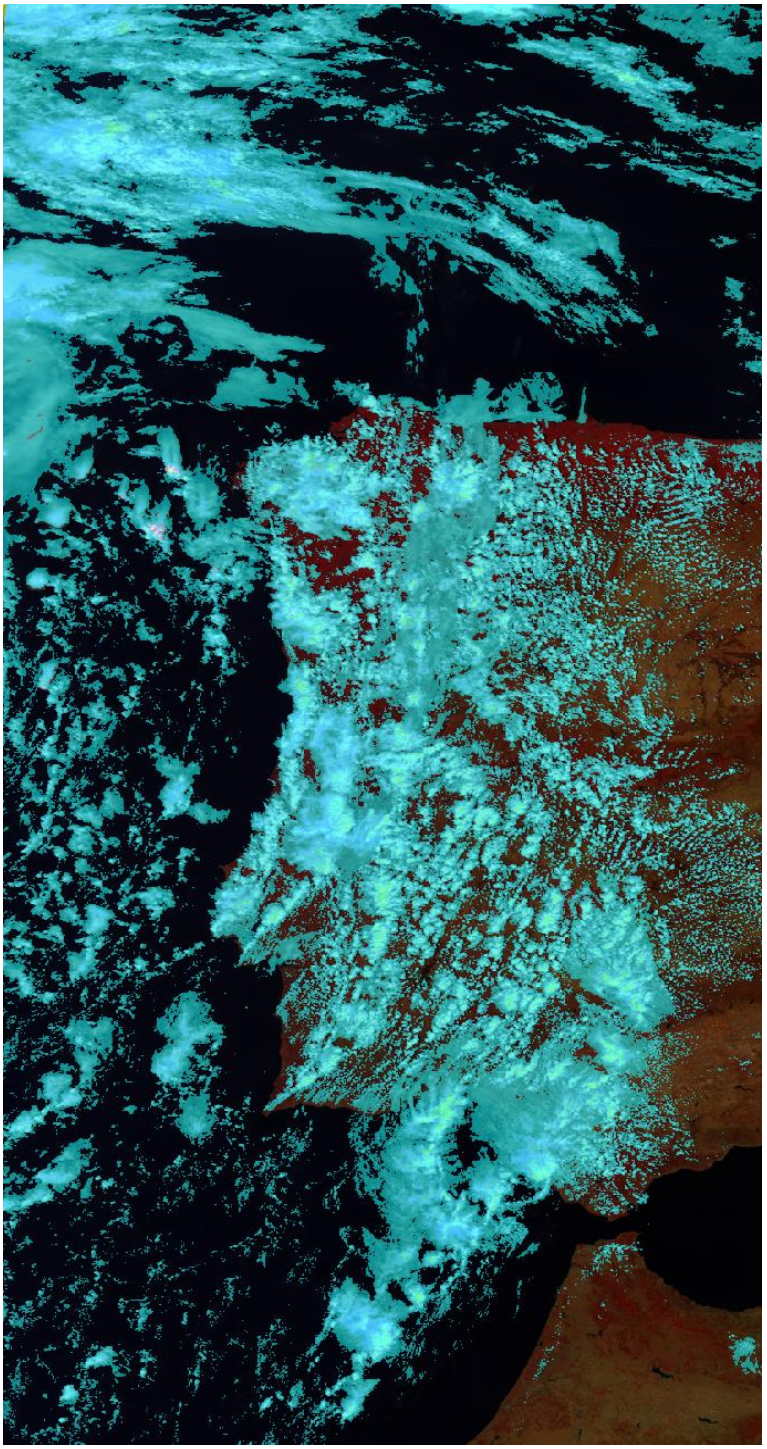


43. The same Fragment (Mediterranean, Crete)
Wrong masking of sun glint area.



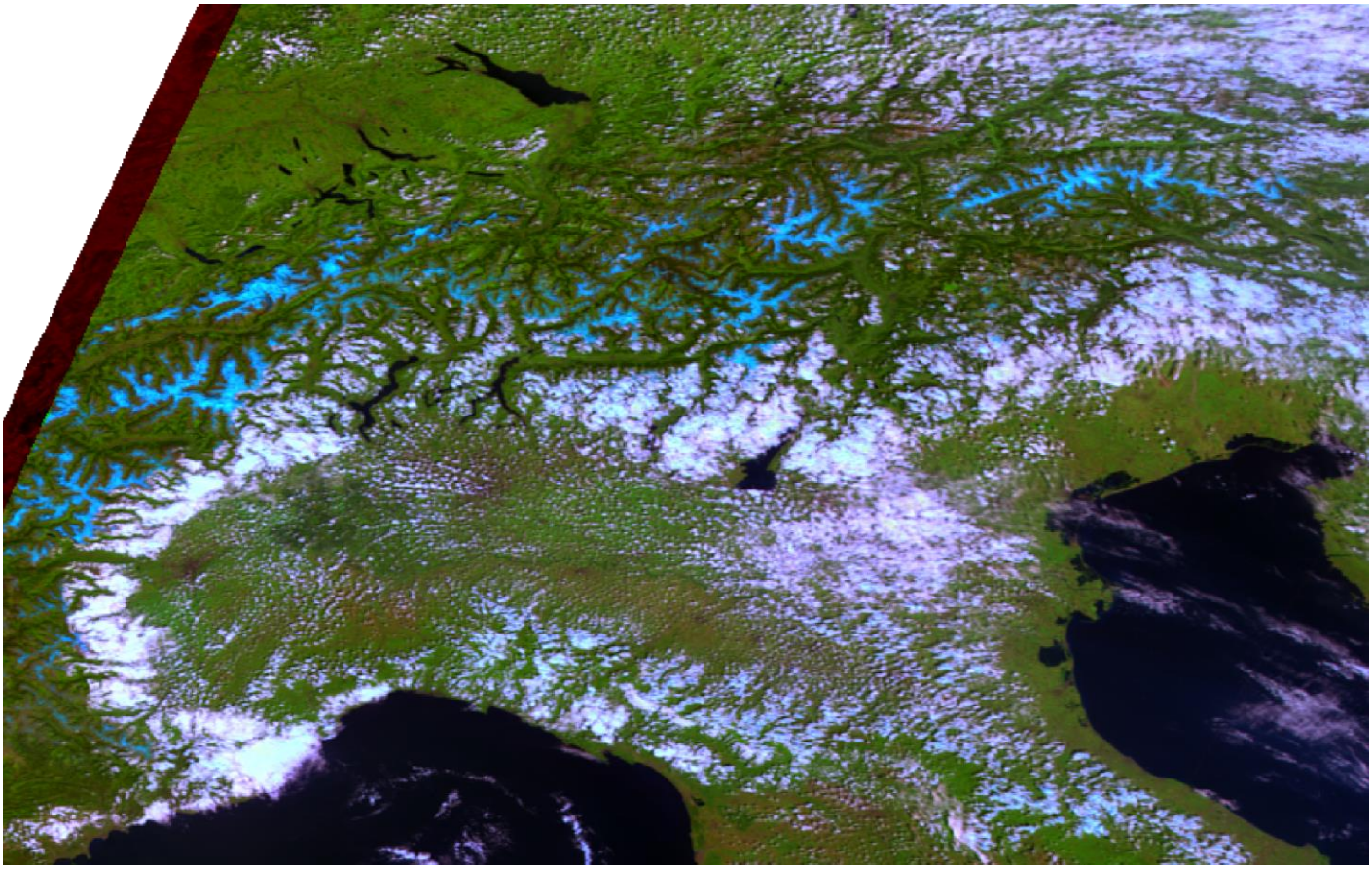
44. PROBAV_L2A_20140621_110705_3_1KM_V103 (Spain)
Well done cloud mask.

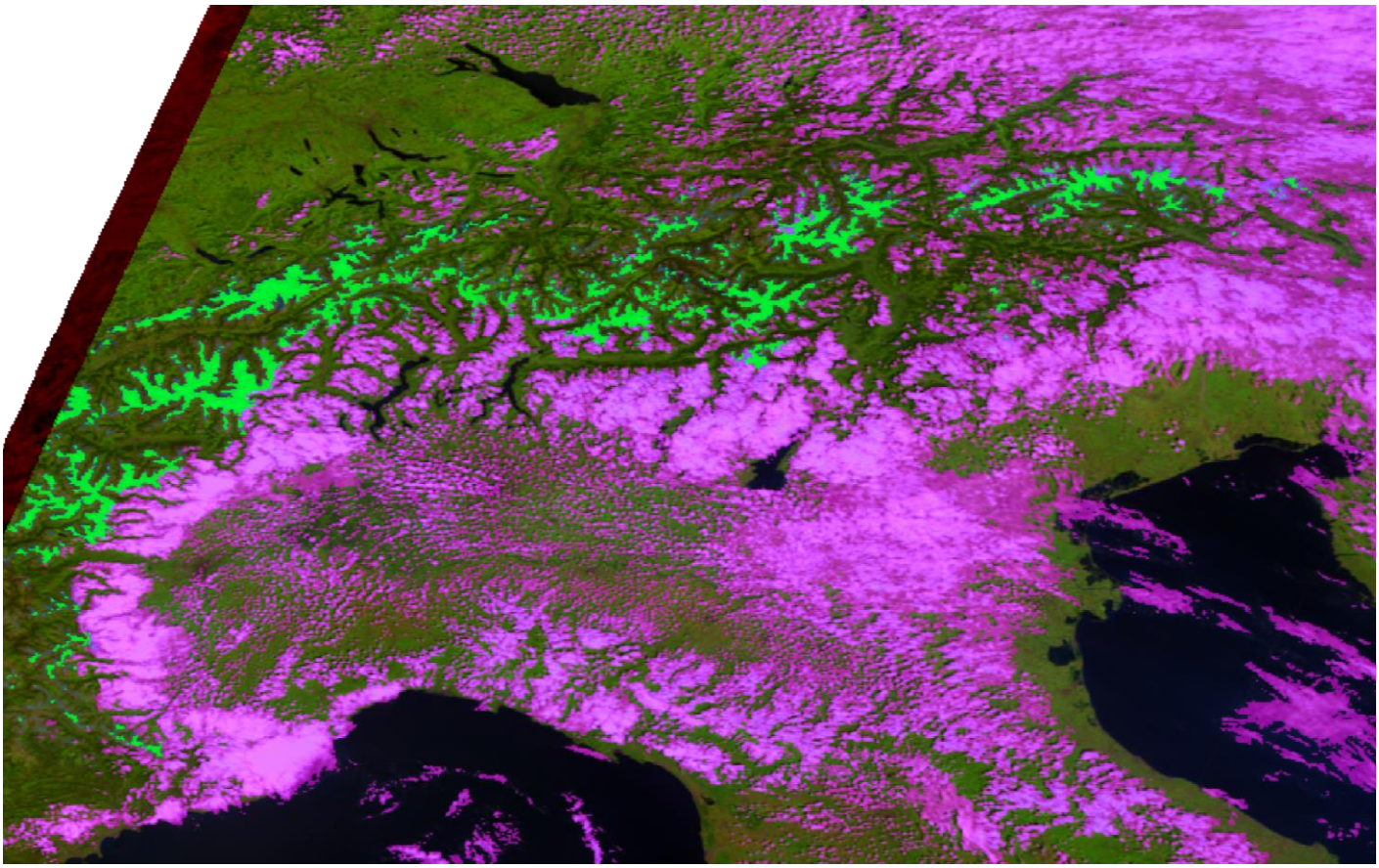




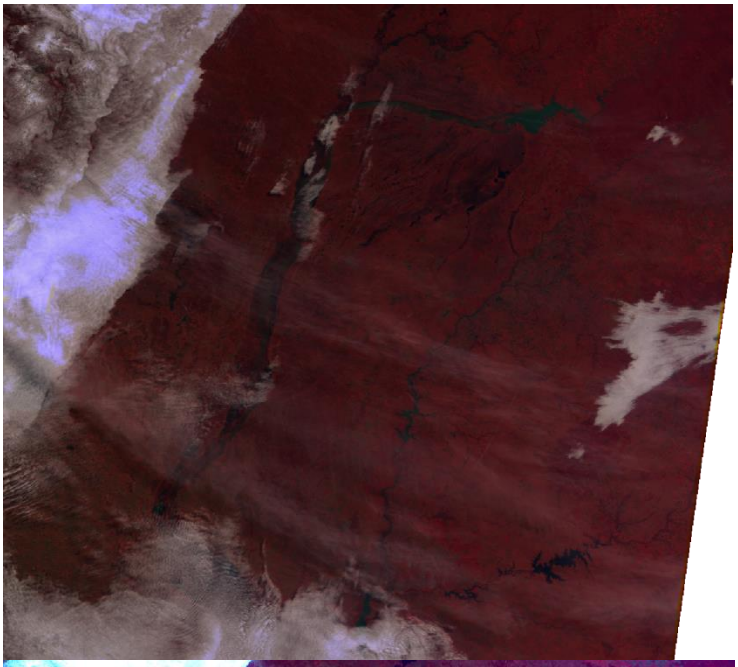
45. PROBAV_L2A_20140621_110758_1_1KM_V103 (Alps)

Everything is fine here as well.

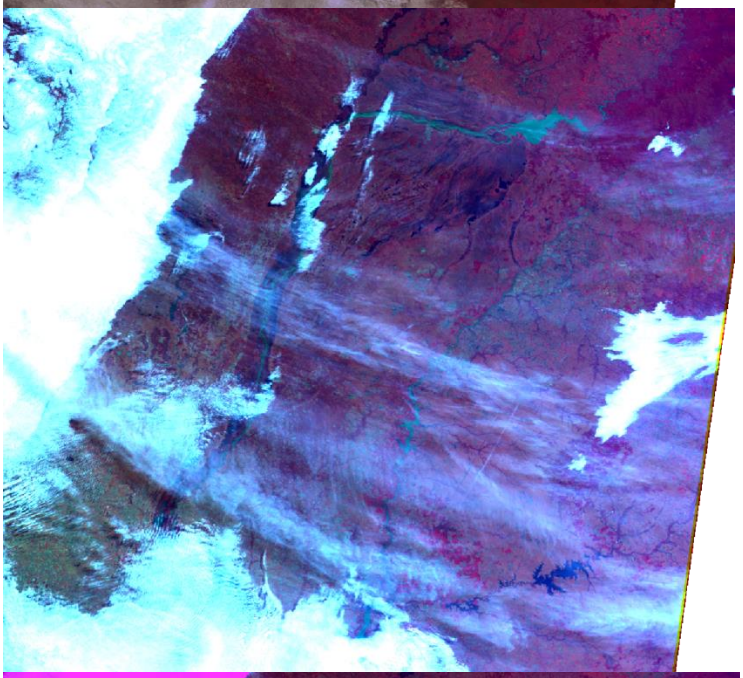




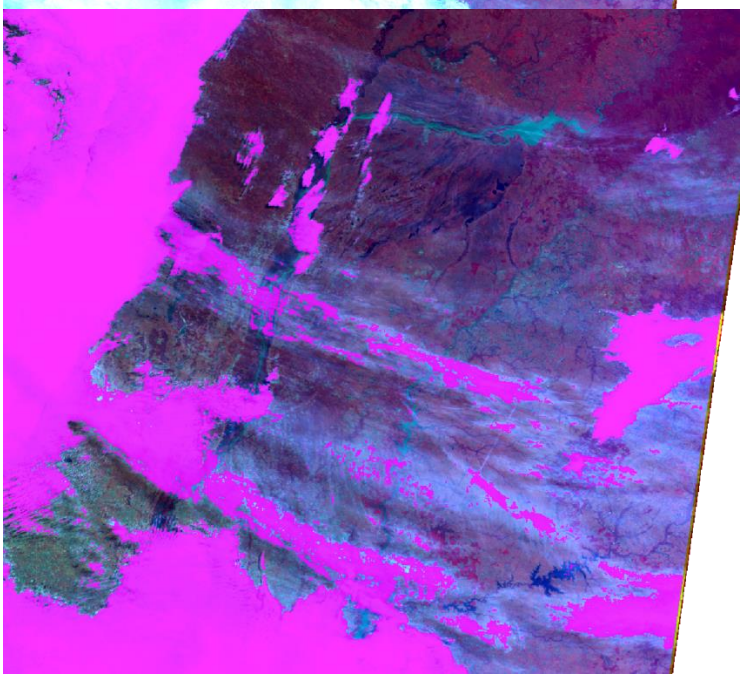
46. PROBAV_L2A_20140621_144544_1_1KM_V103 (Uruguay)



← RGB 1



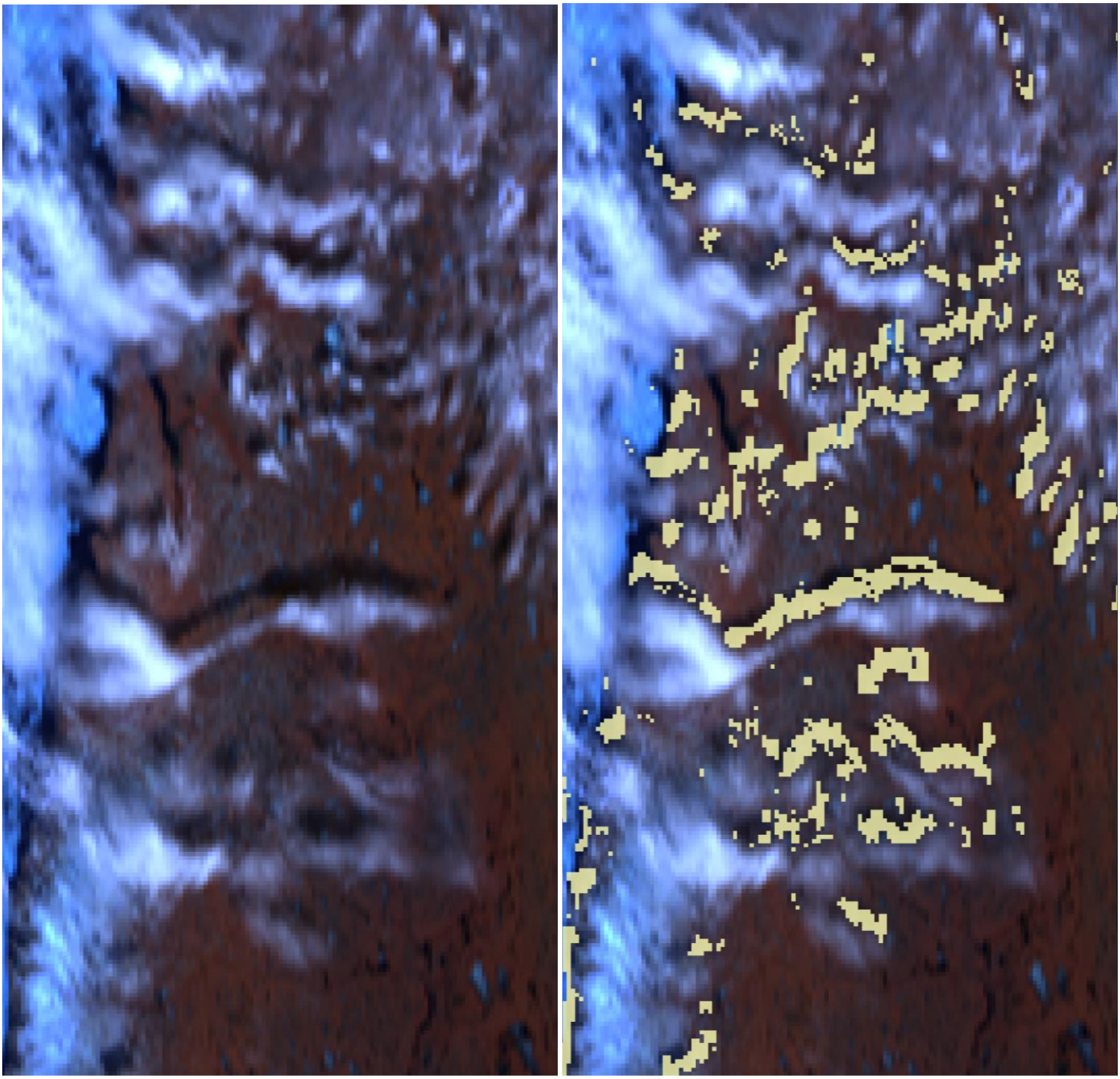
← RGB strongly contrasted



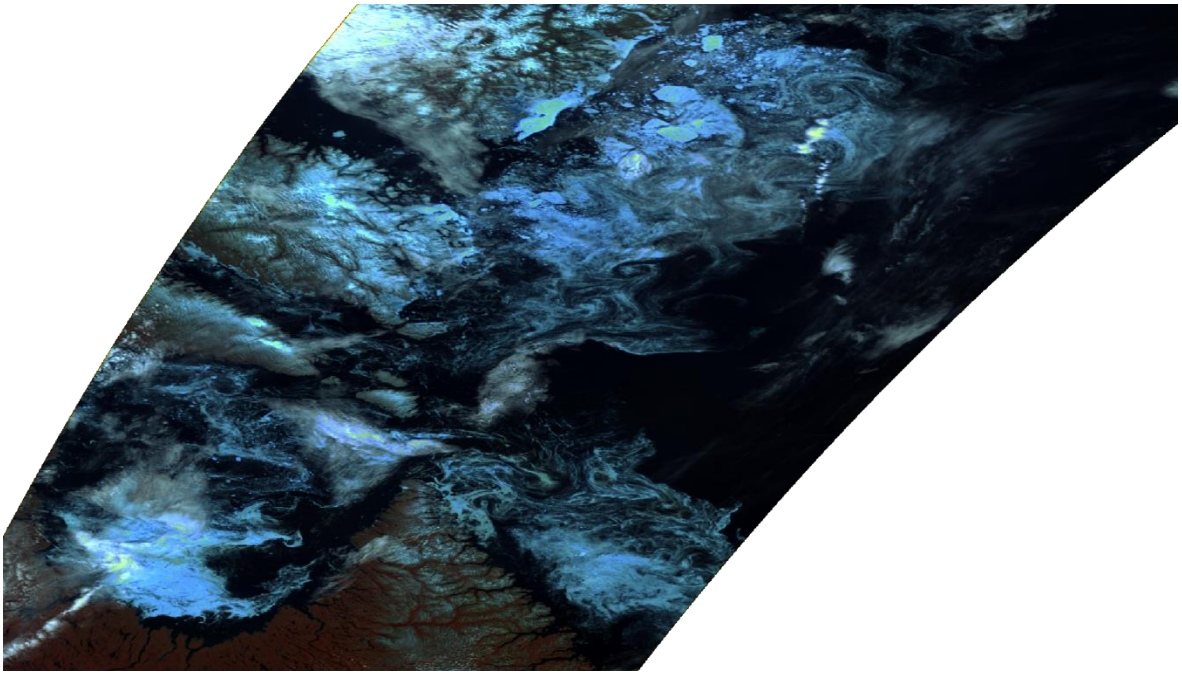
← Clouds mask

It can be seen that not all semi-transparent clouds are masked as such.

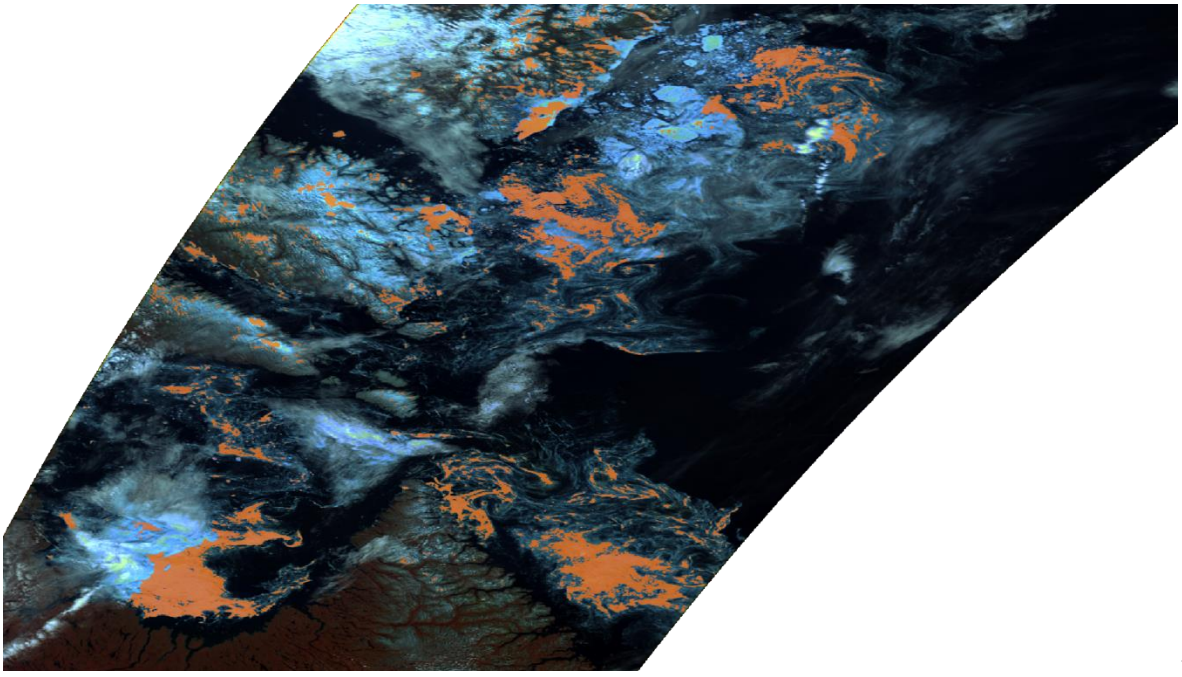
47. PROBAV_L2A_20140621_160704_3_1KM_V103 (Canada, peninsula D' Ungava, in the North of Akulivik)
Cloud shadows



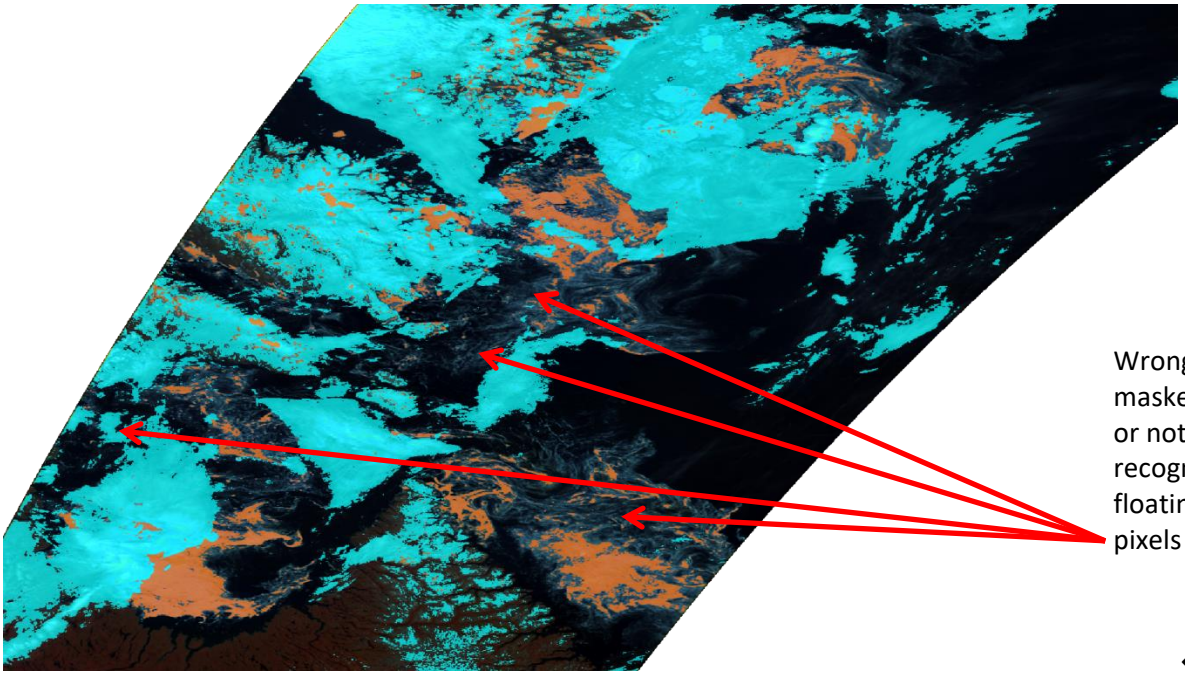
48. PROBAV_L2A_20140621_160704_3_1KM_V103 (Hudson Strait)



← Floating ice



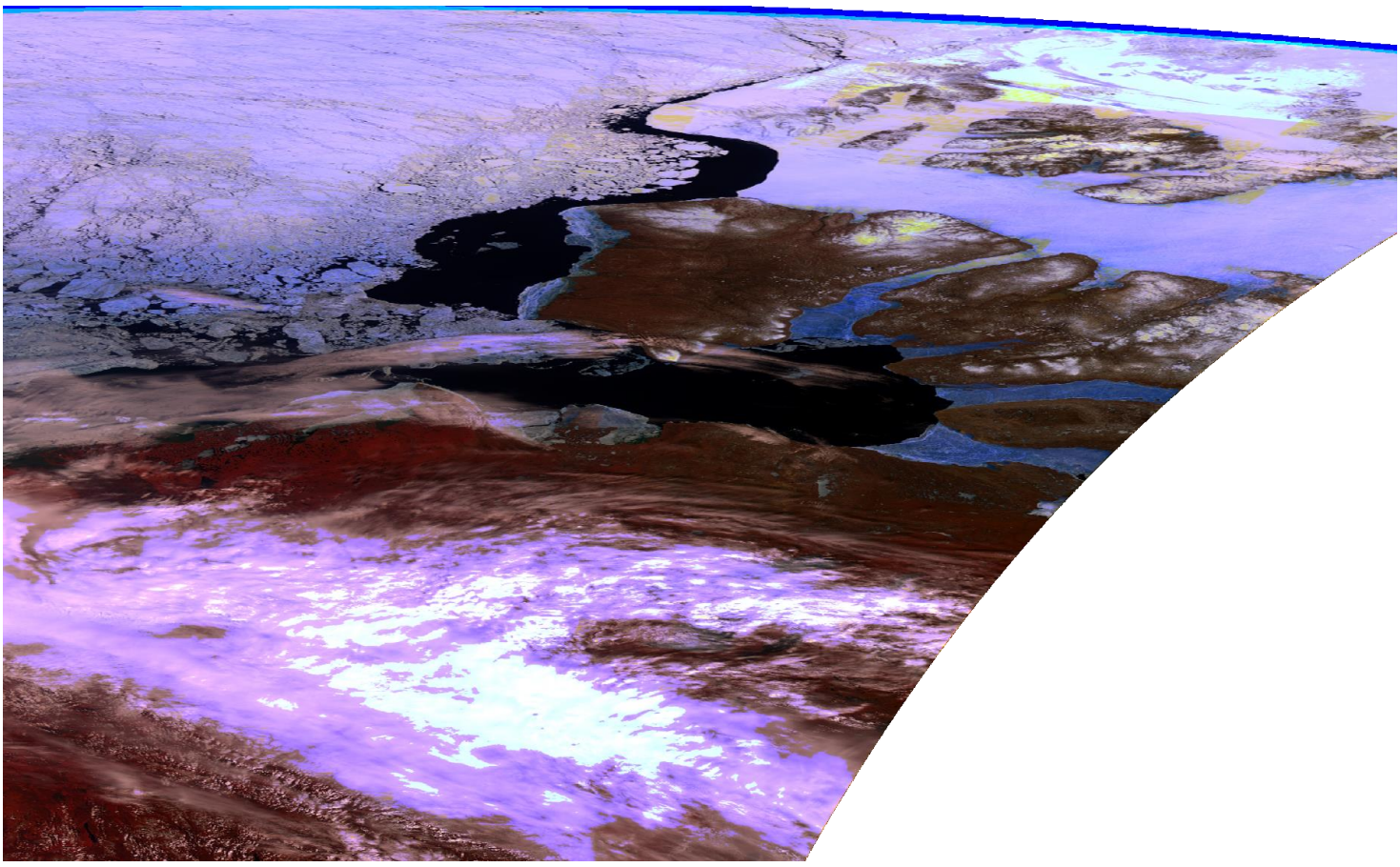
← Ice mask

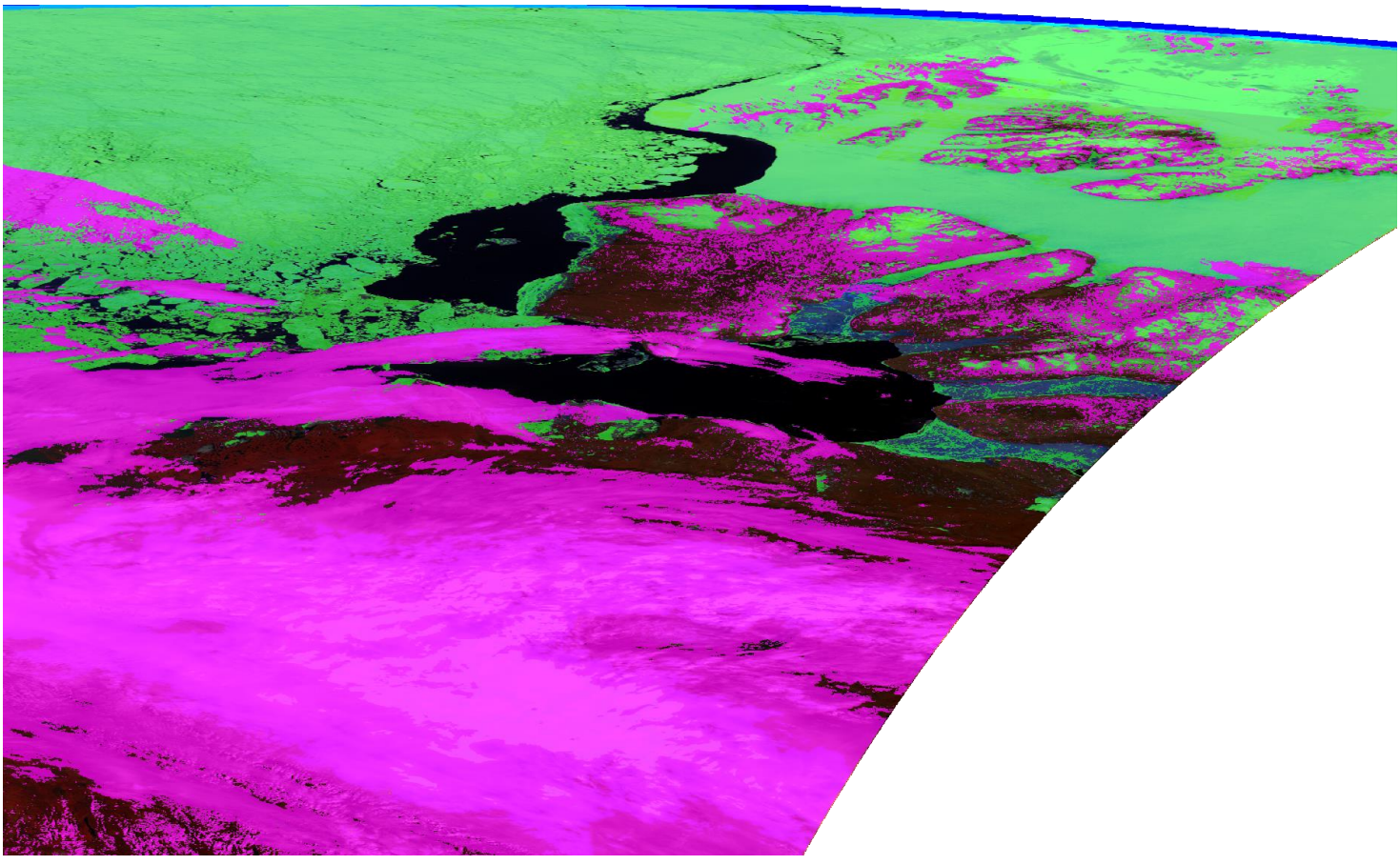


Wrong masked or not recognized floating ice pixels

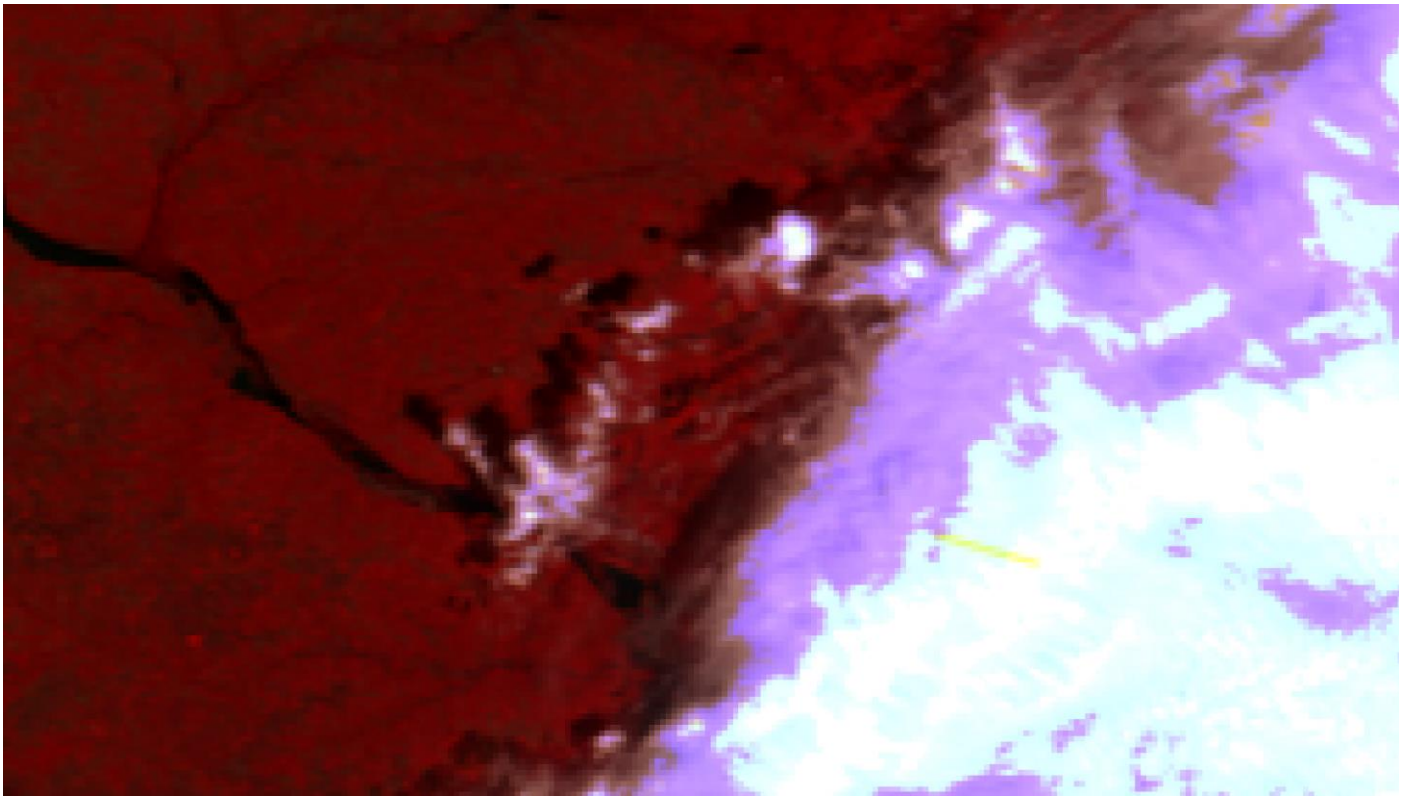
← Ice- & cloud mask

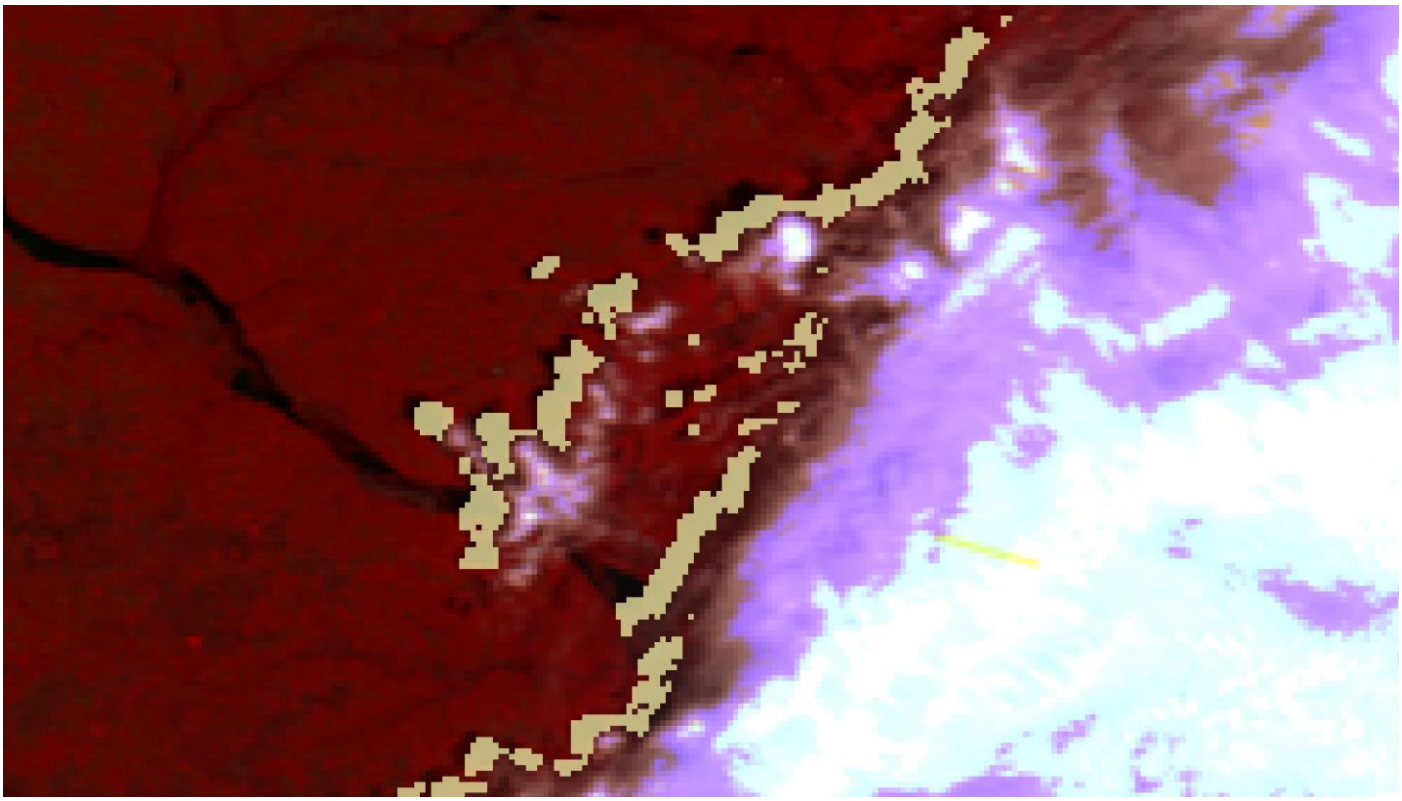
49. PROBAV_L2A_20140621_192935_3_1KM_V103 (Canadian arctic archipelago)
Pretty good ice and cloud mask, except for dark sea ice



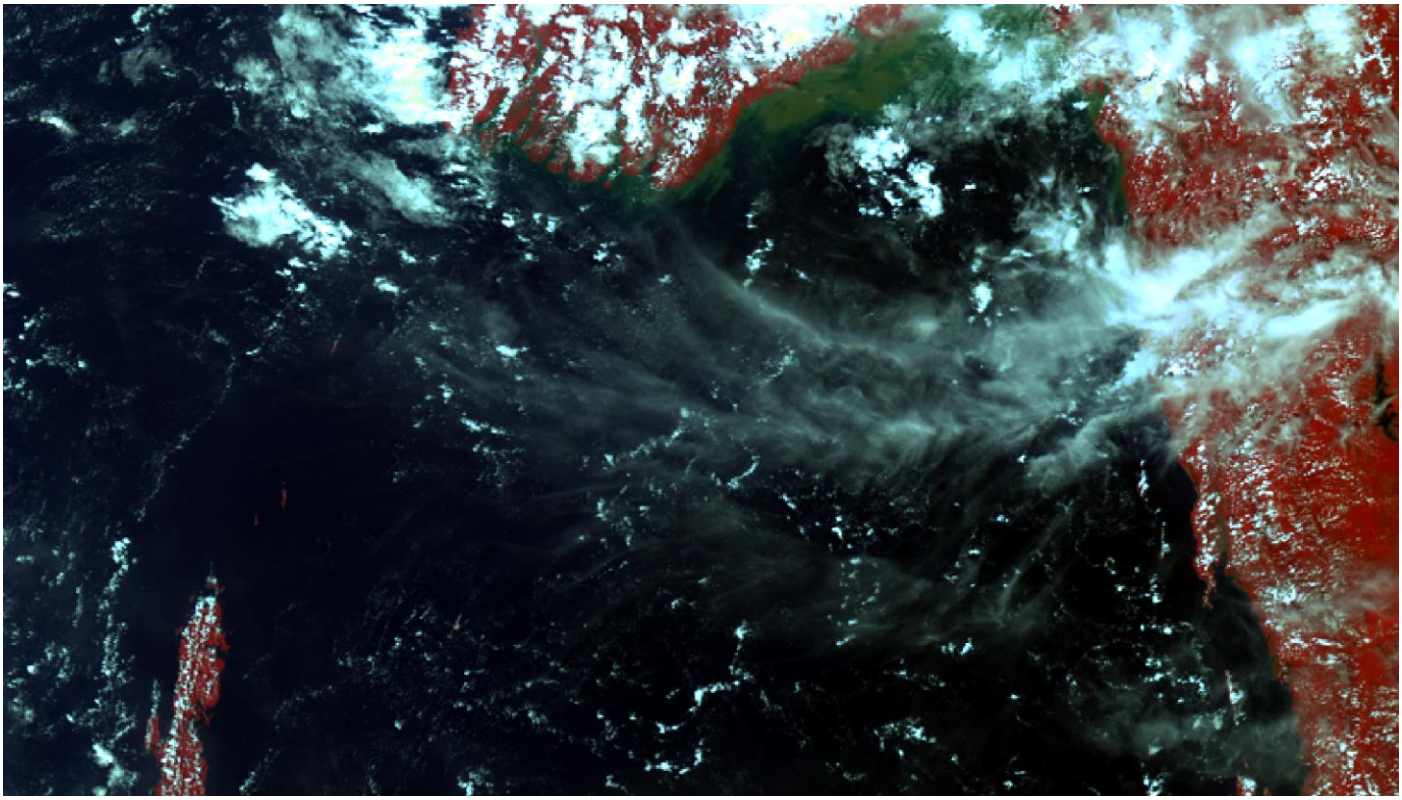


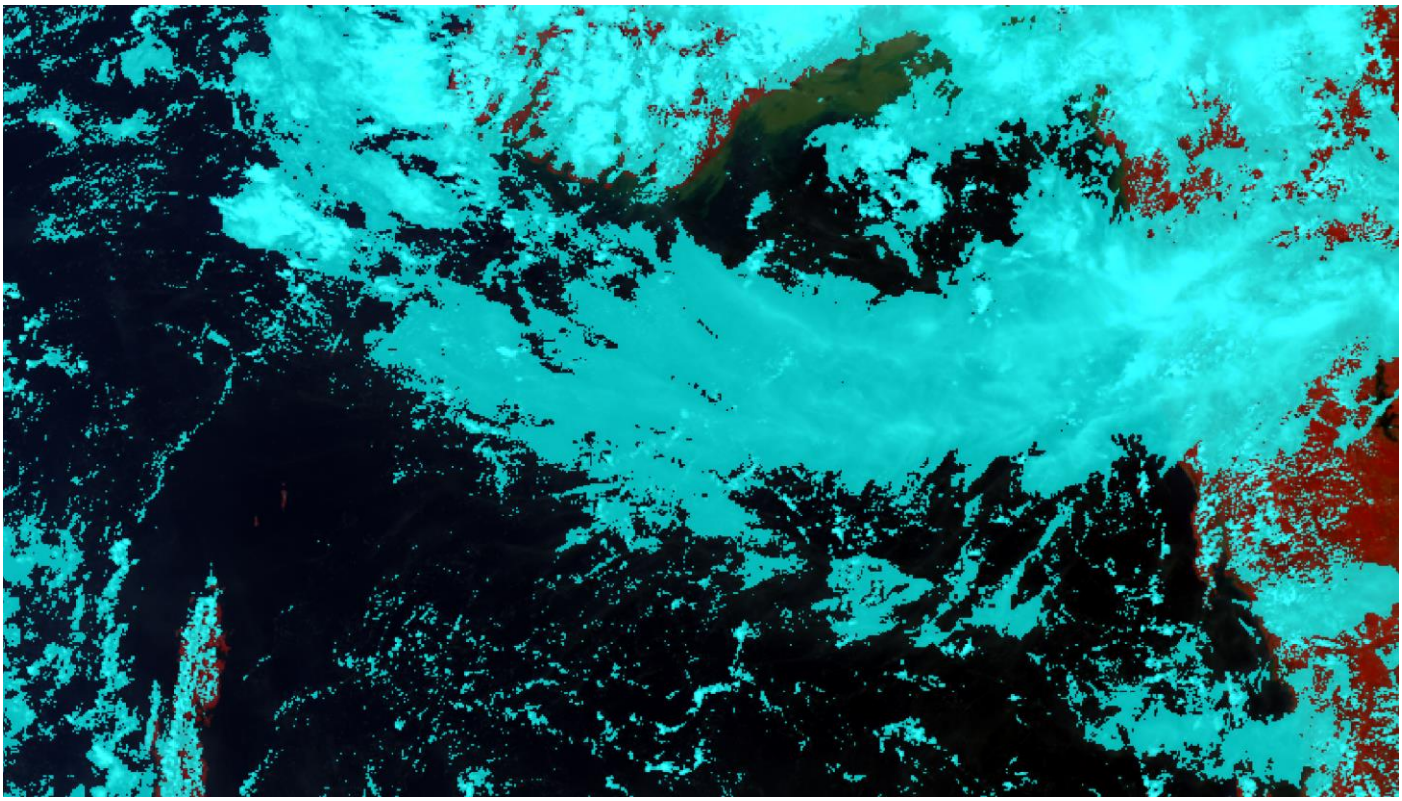
50. PROBAV_L2A_20140621_175302_1_1KM_V103 (South America)
Cloud shadows



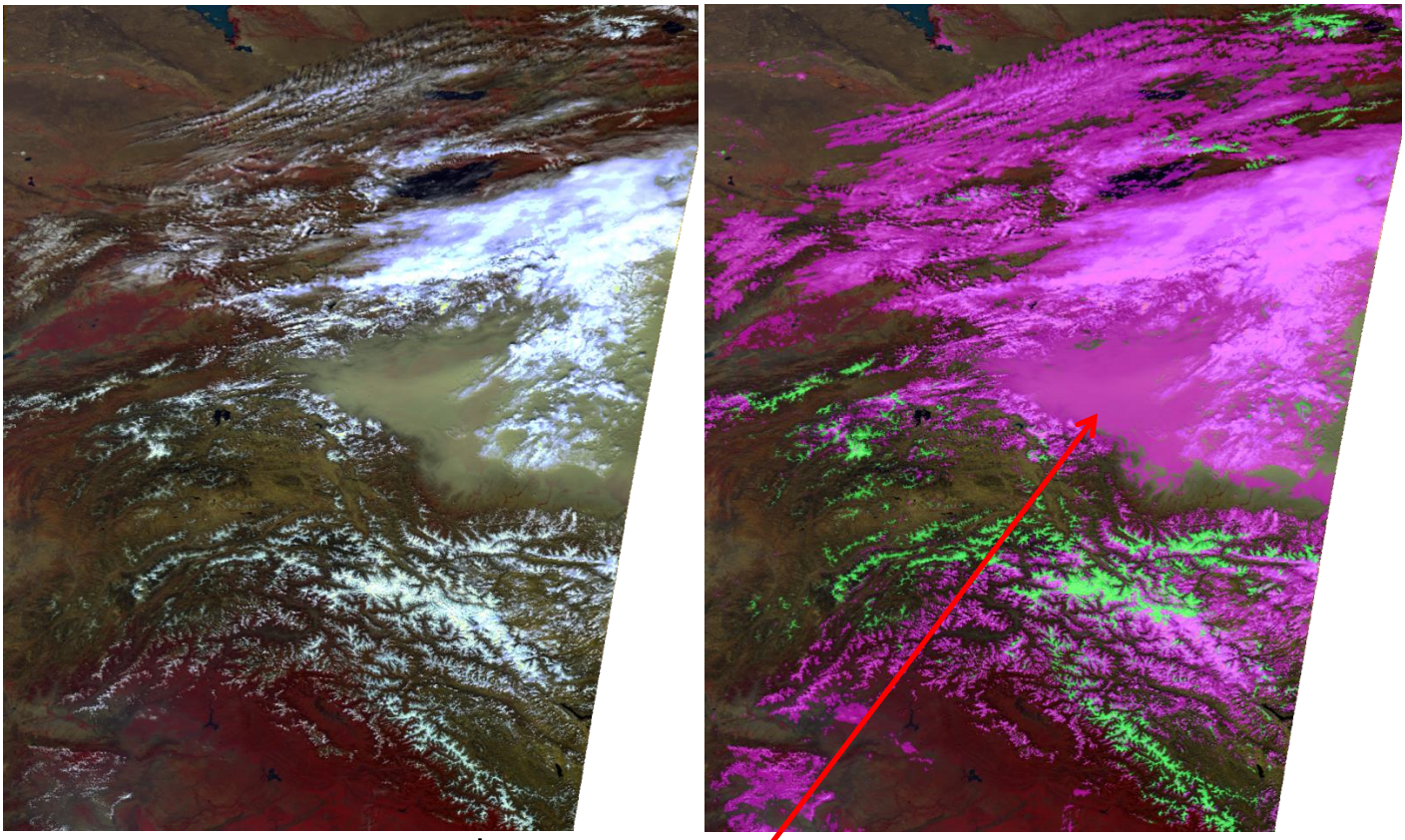


51. PROBAV_L2A_20140621_035355_3_1KM_V103 (Northeast of Indian Ocean, Andaman Islands)
The well done cloud mask

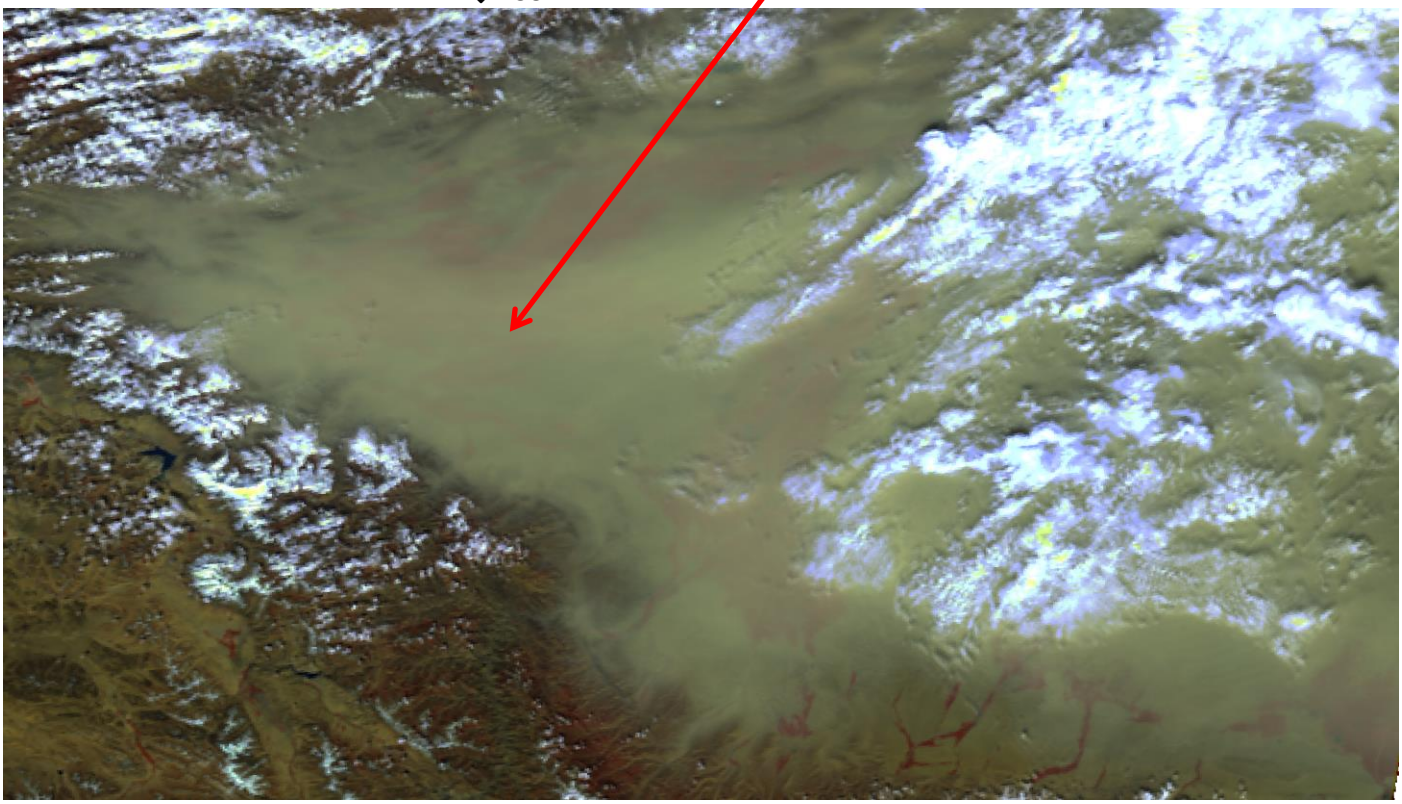




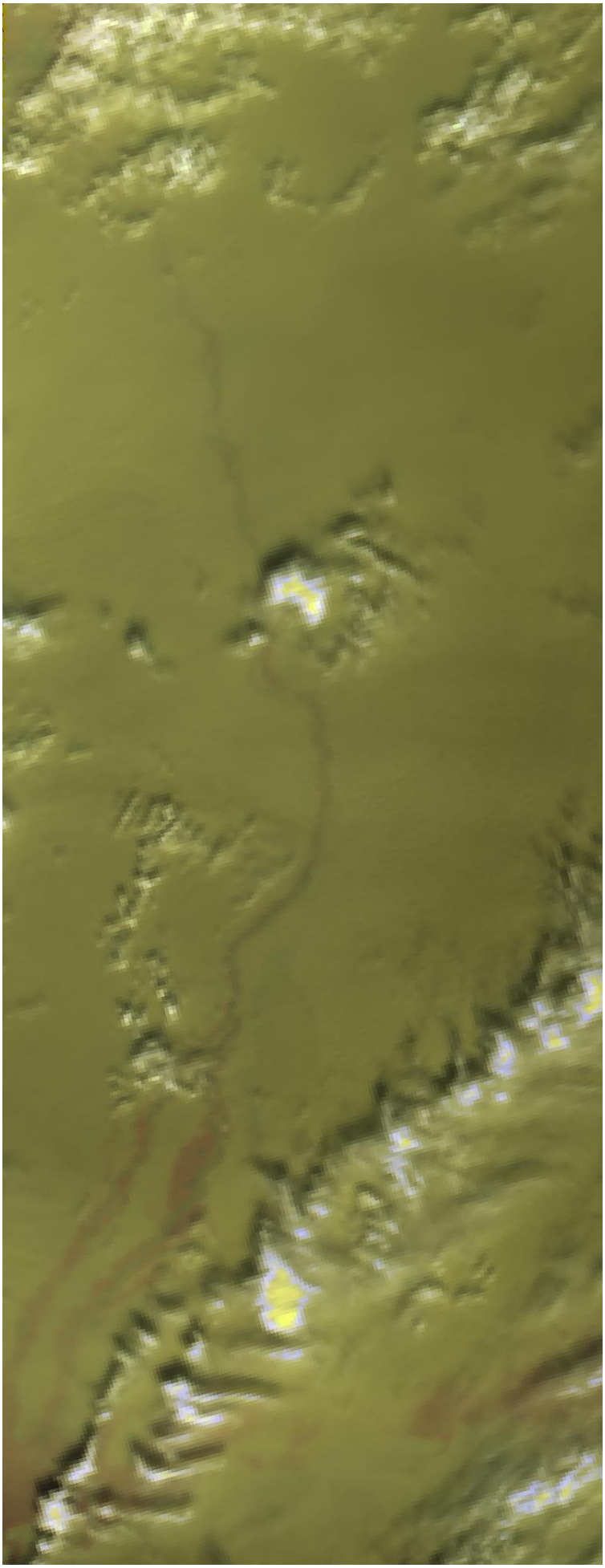
52. PROBAV_L2A_20140621_053508_3_1KM_V103 (West of Takla Makan Desert)
Aerosol covered desert (sandstorm, dust) marked as cloudy.
Is that correct?

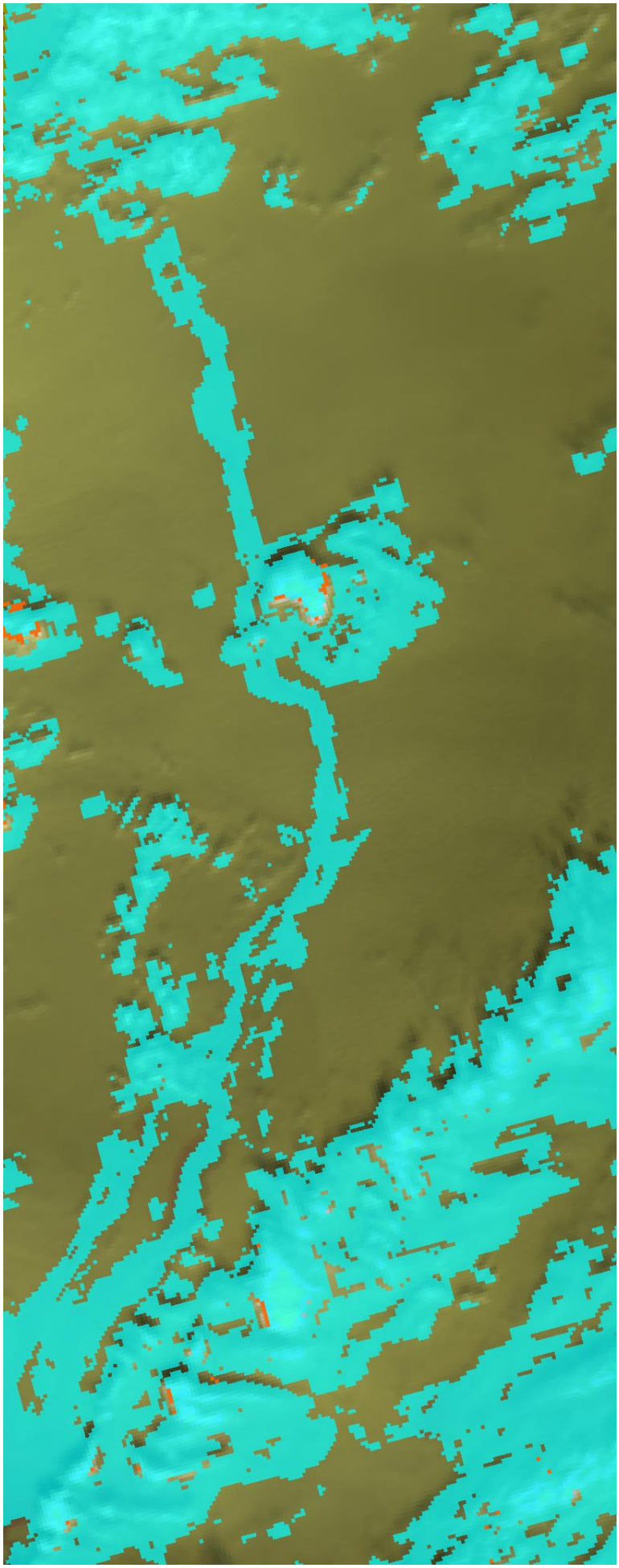


↓ zoom



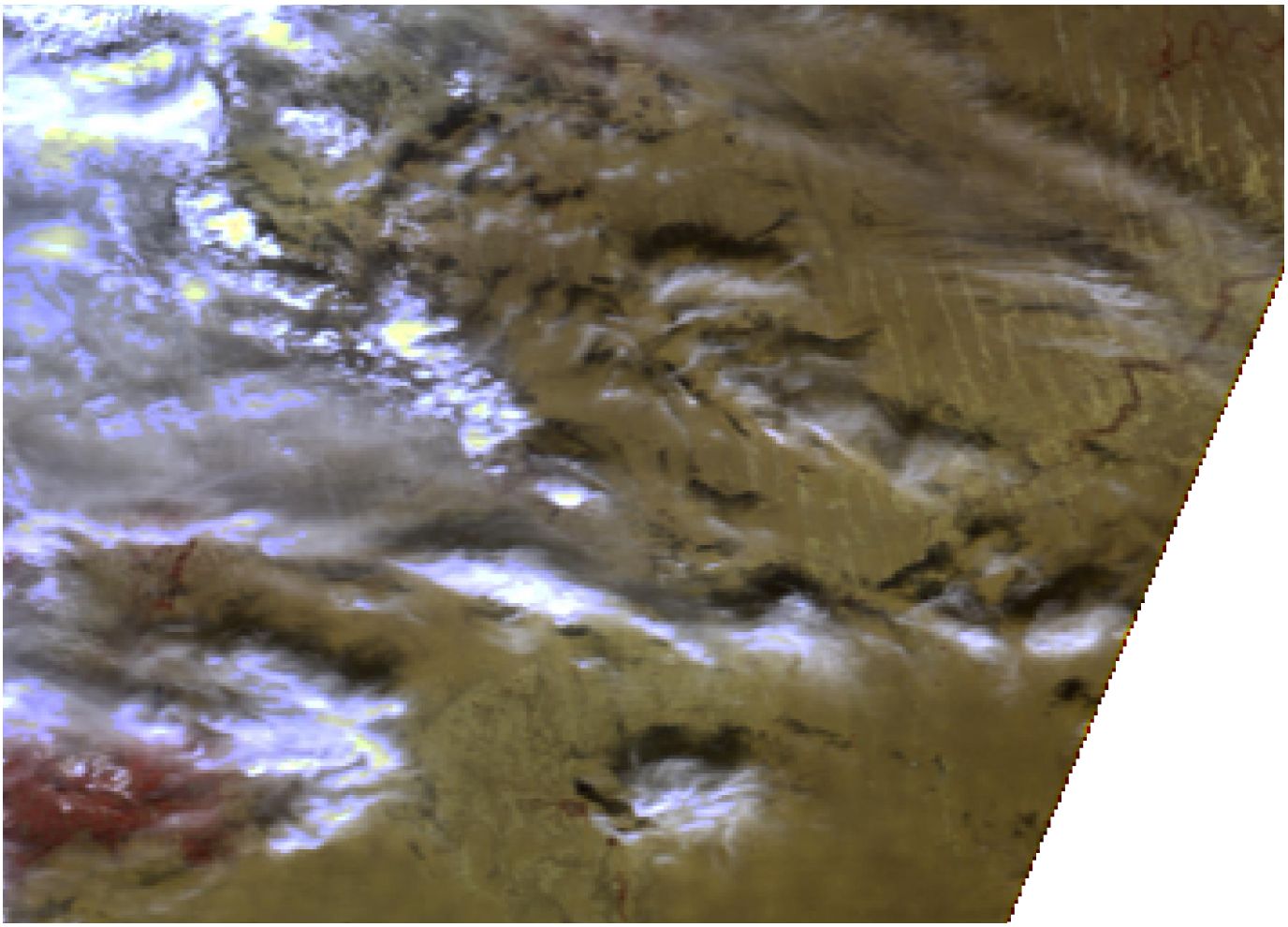
53. PROBAV_L2A_20140621_053530_2_1KM_V103 (Takla Makan Desert)
A dried riverbed is wrong marked as cloudy.
Some cloud pixels are labelled as snow covered.

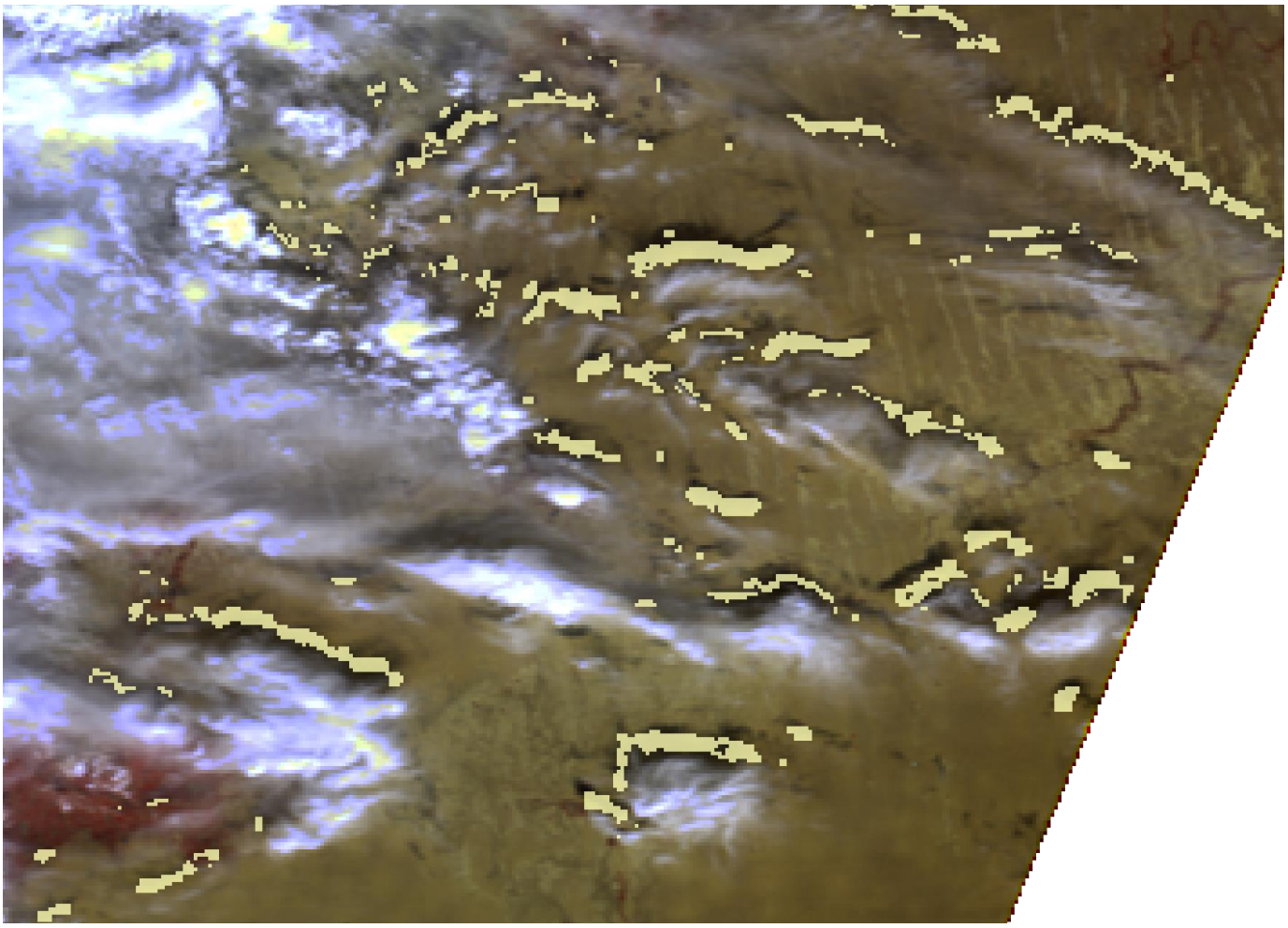




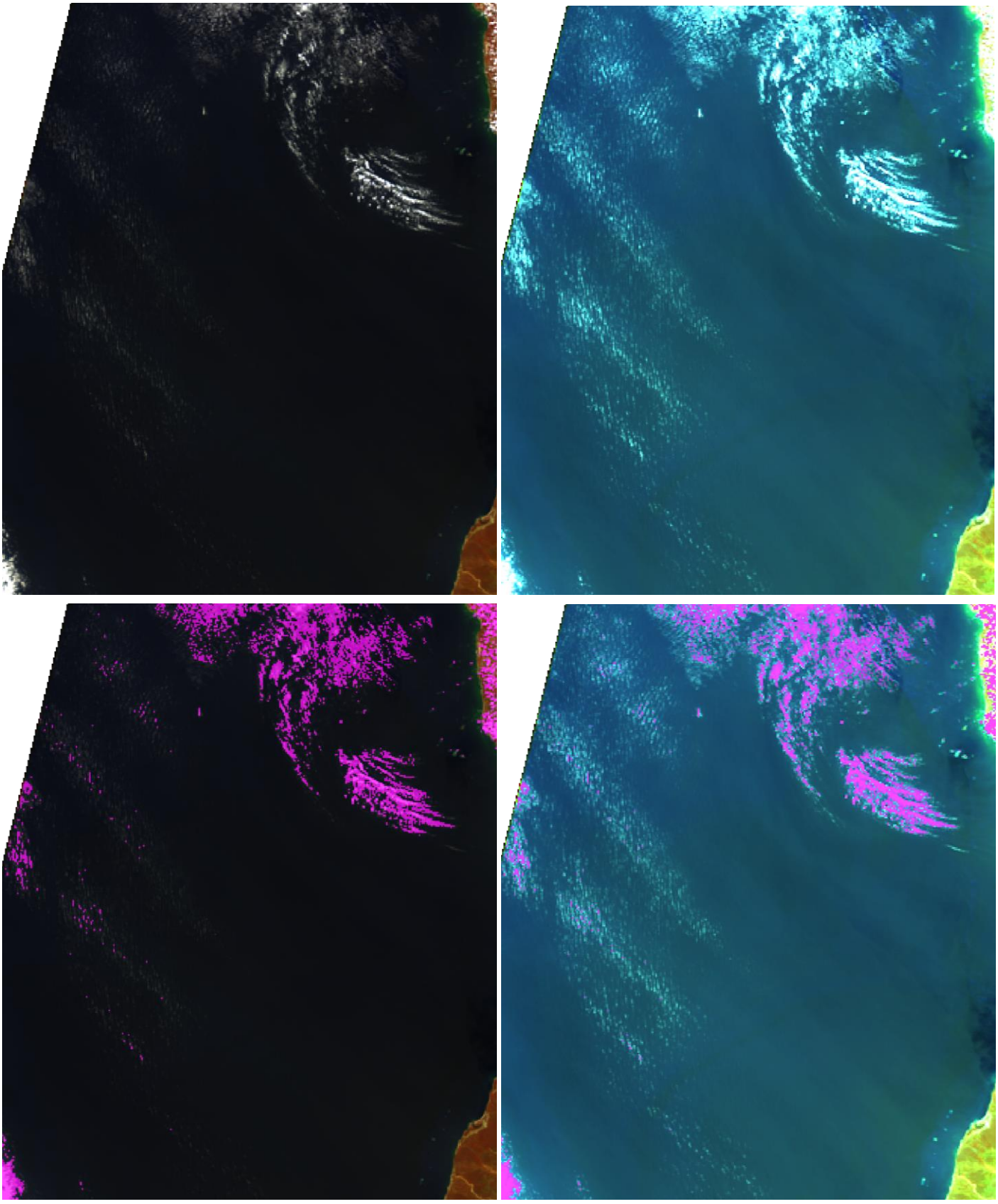
54. PROBAV_L2A_20140621_071646_2_1KM_V103 (From Ural Mountains to Horn of Africa ⊙ 9,5)

55. The same Fragment (Karakum Desert)
Cloud shadows (a bit too narrow)

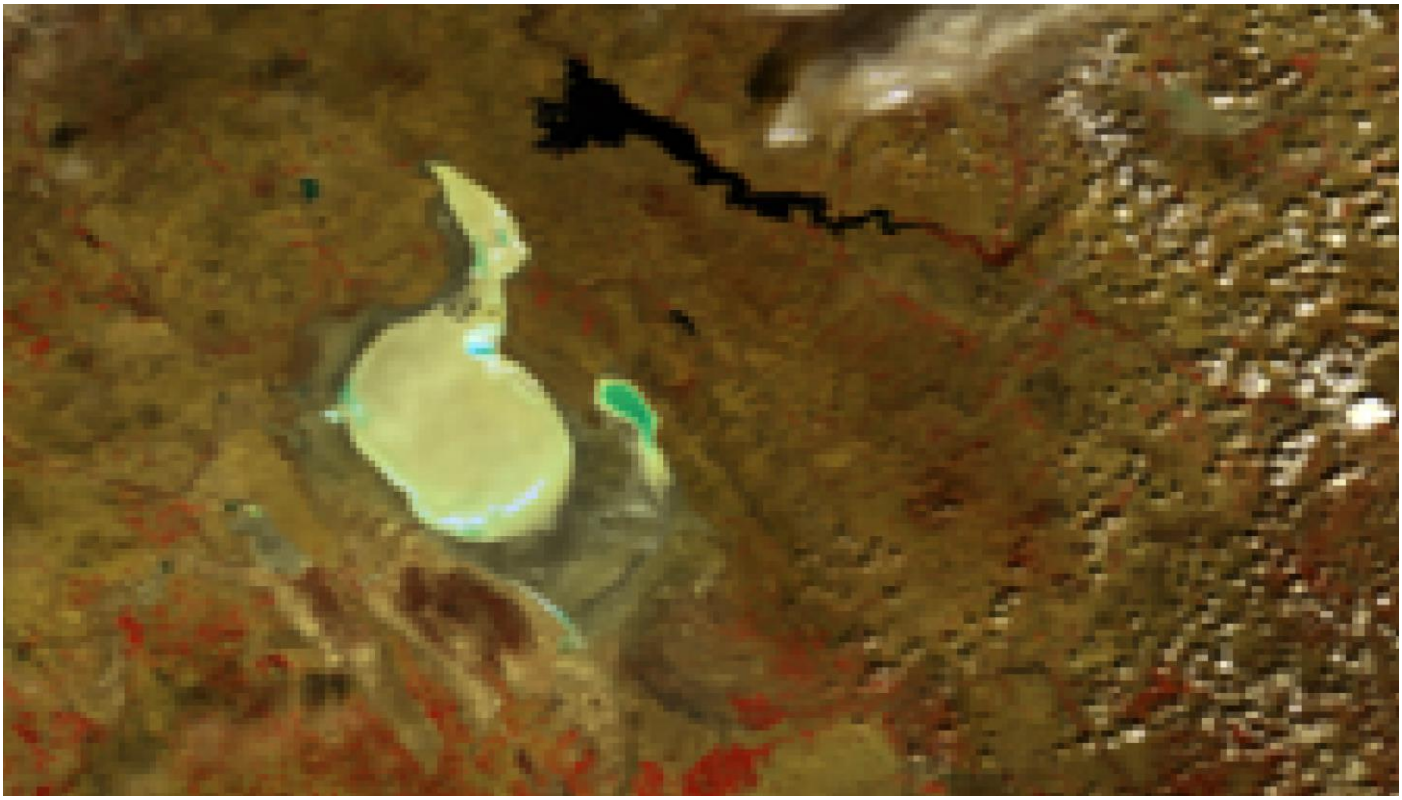


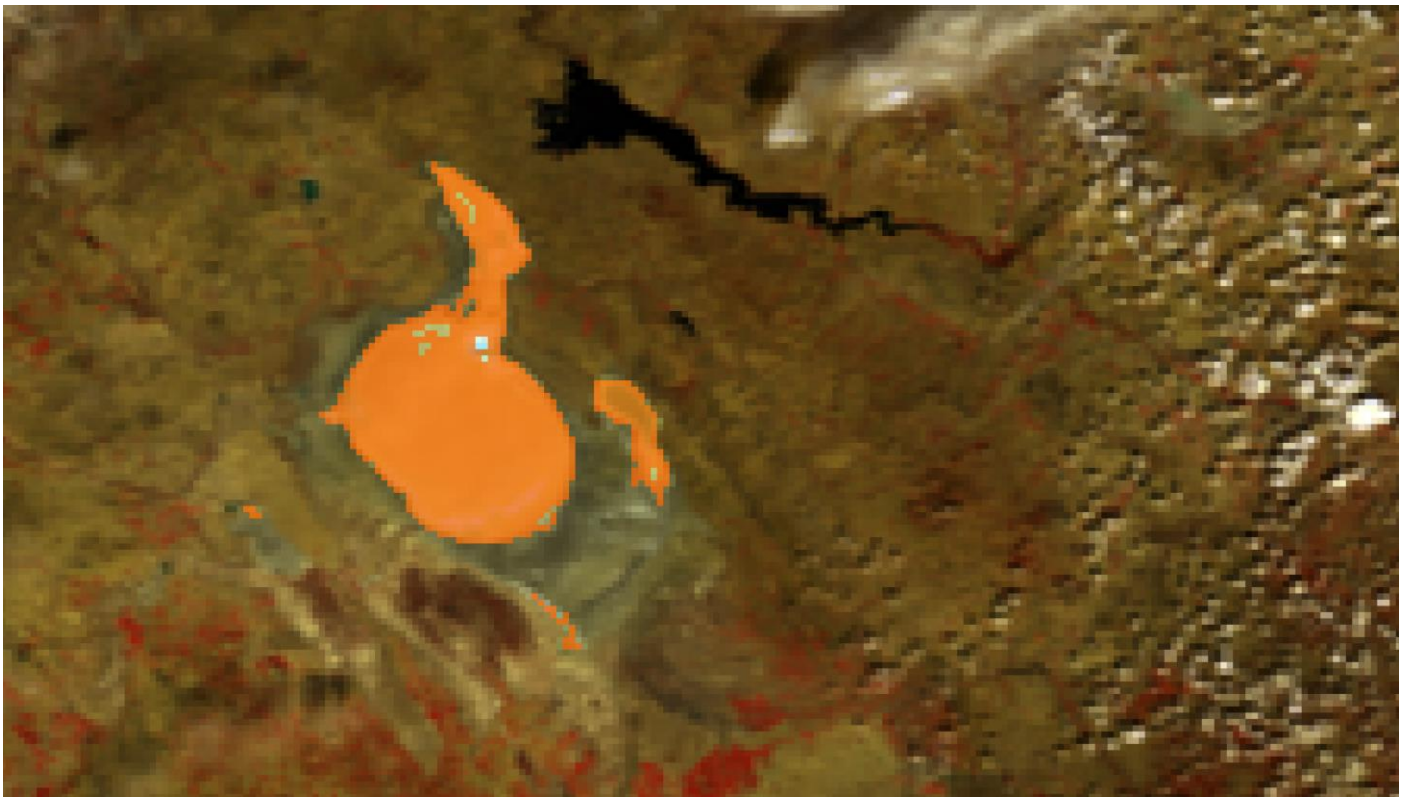


56. PROBAV_L2A_20140621_074055_2_1KM_V103 (Strait of Mozambique)
Some very thin and spatially mixed clouds are not recognized



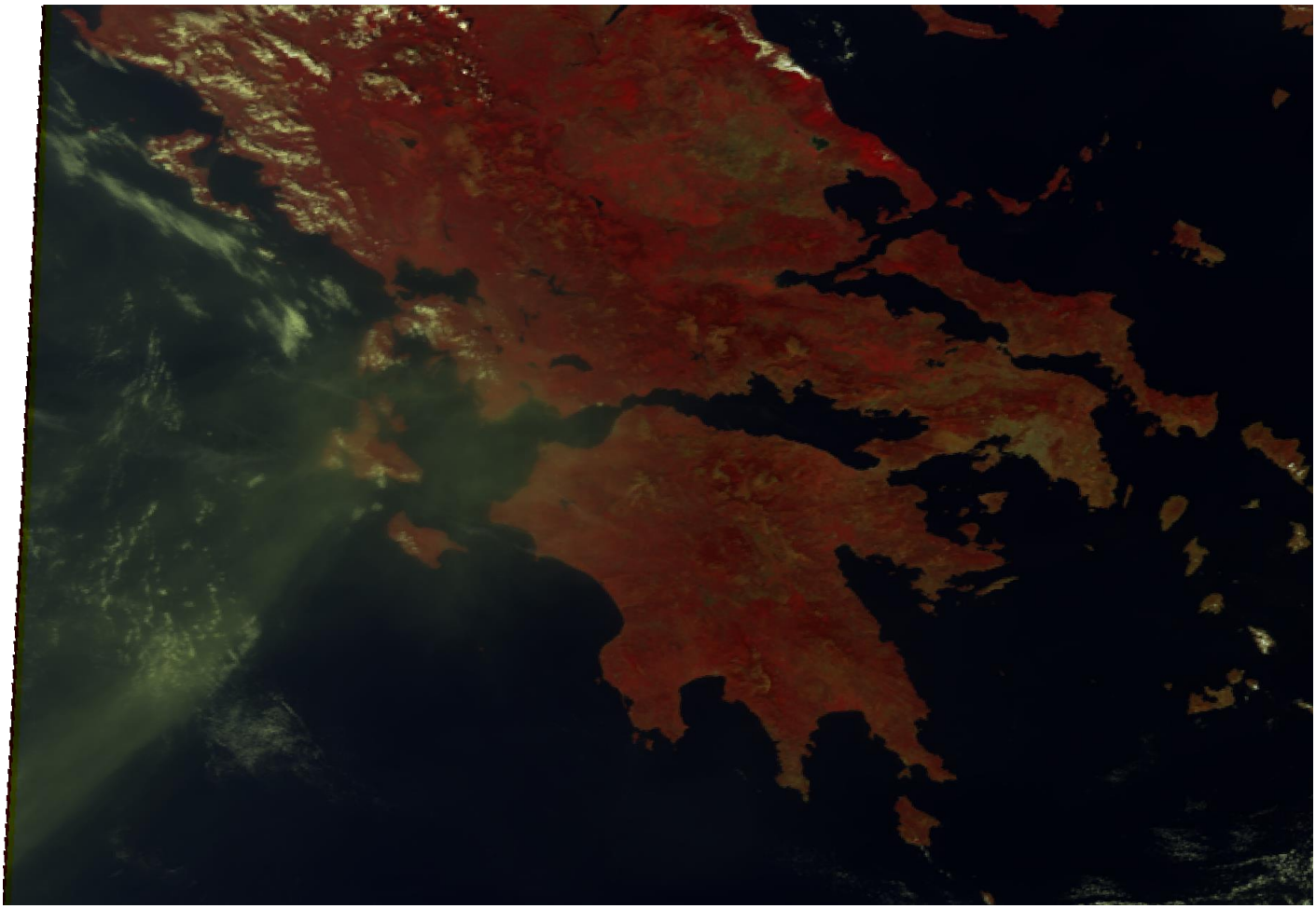
57. PROBAV_L2A_20140621_085802_2_1KM_V103 (Tuz Gölü, salt, partially dry lake)
The bright surface of salt lake is wrong marked as snow / ice covered

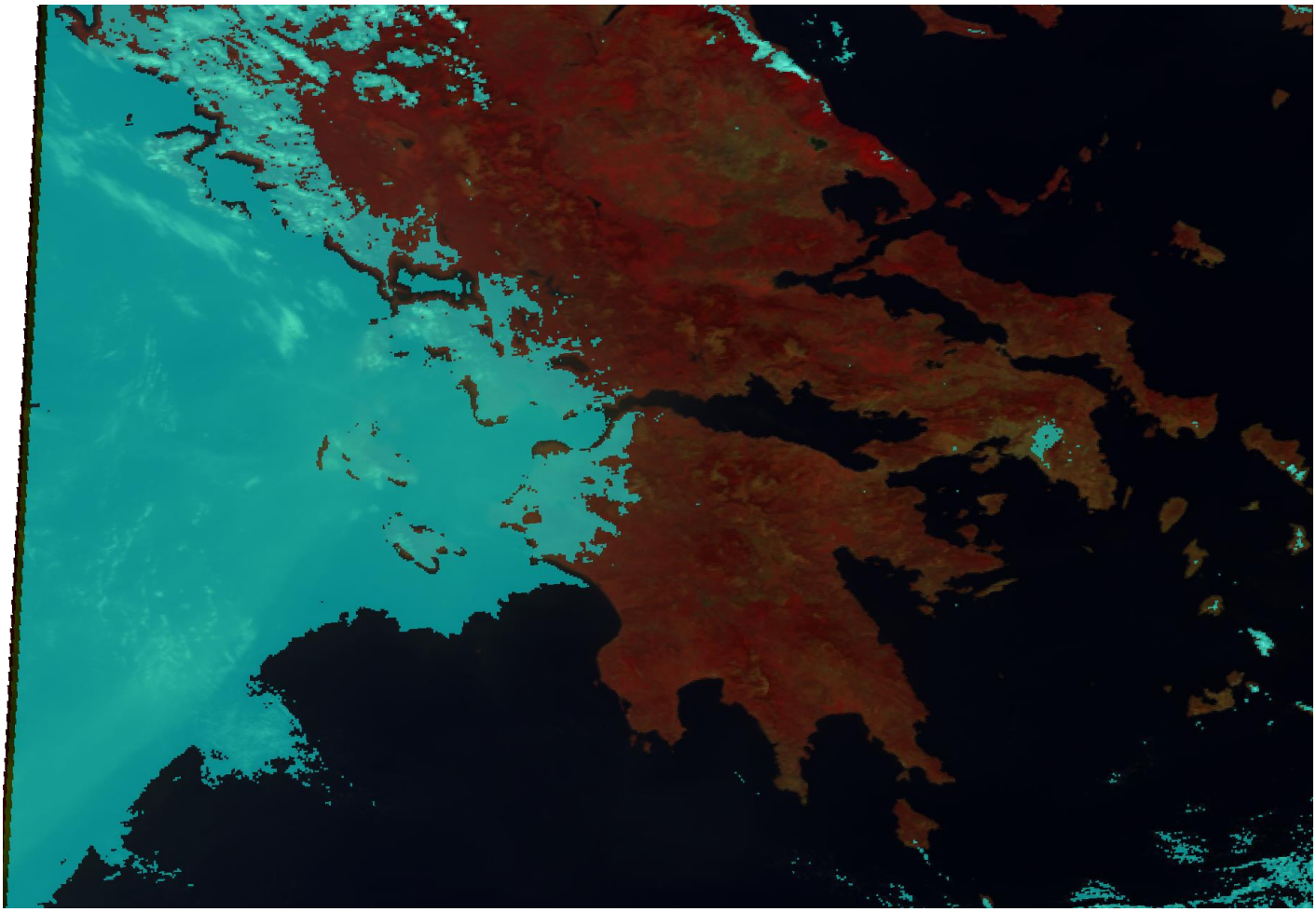




58. PROBAV_L2A_20140621_085937_3_1KM_V103 (Ionian Sea, Greece)

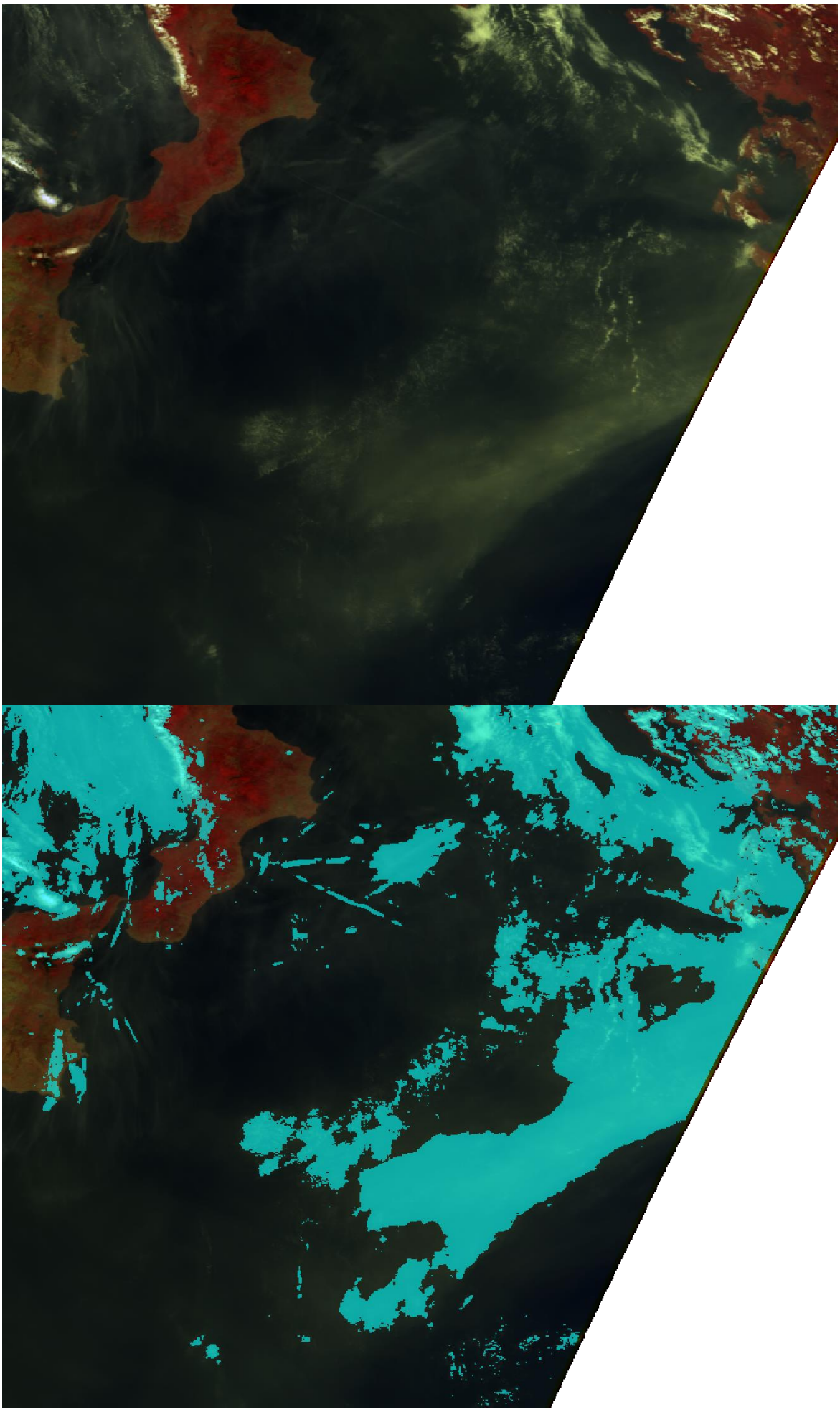
It is a sand storm over Ionian Sea. It is labelled as cloudy. Is it correct?





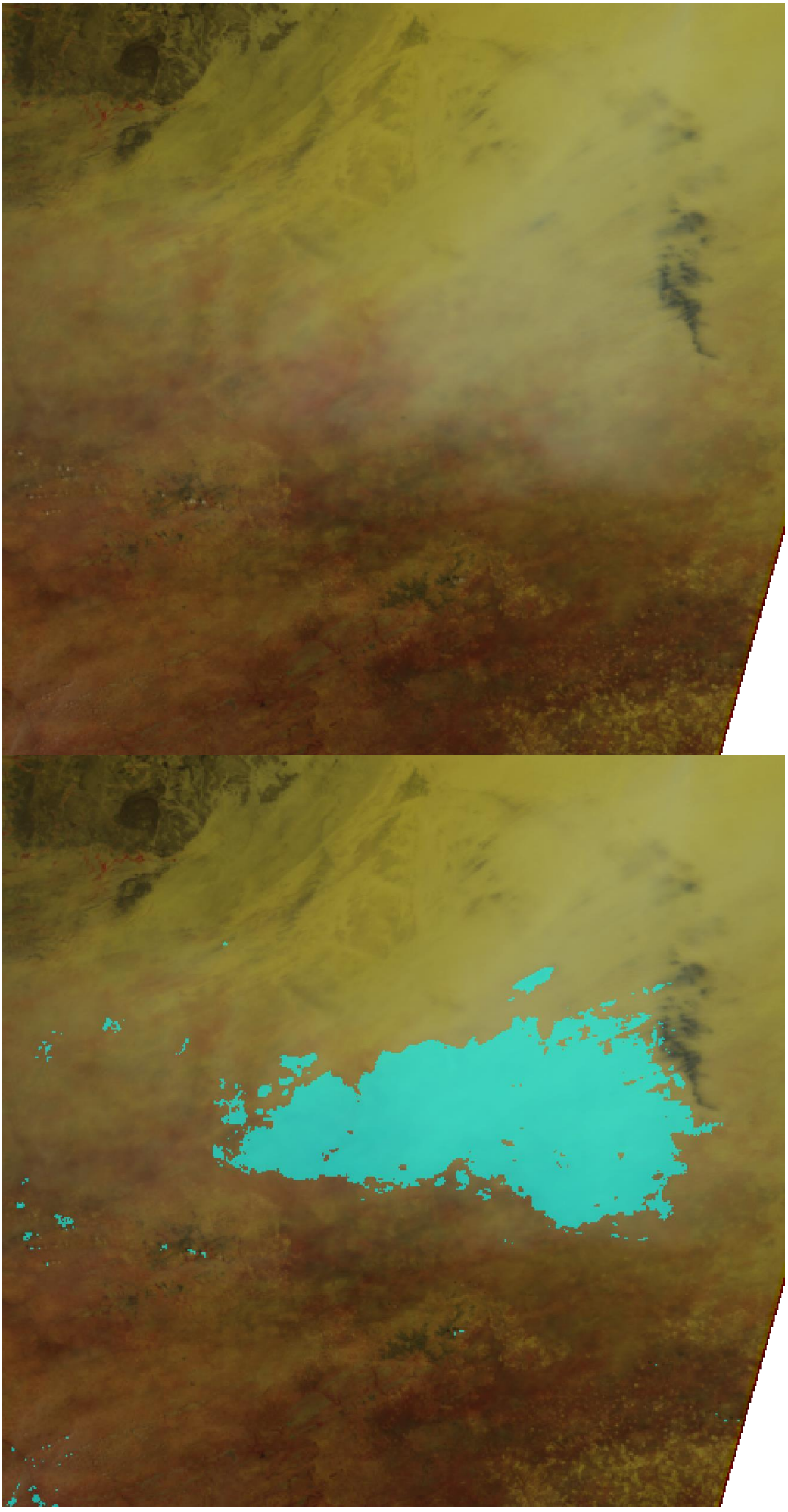
59. PROBAV_L2A_20140621_104339_1_1KM_V103 (Ionian Sea, Italy)

The same situation as in the Nr. 57

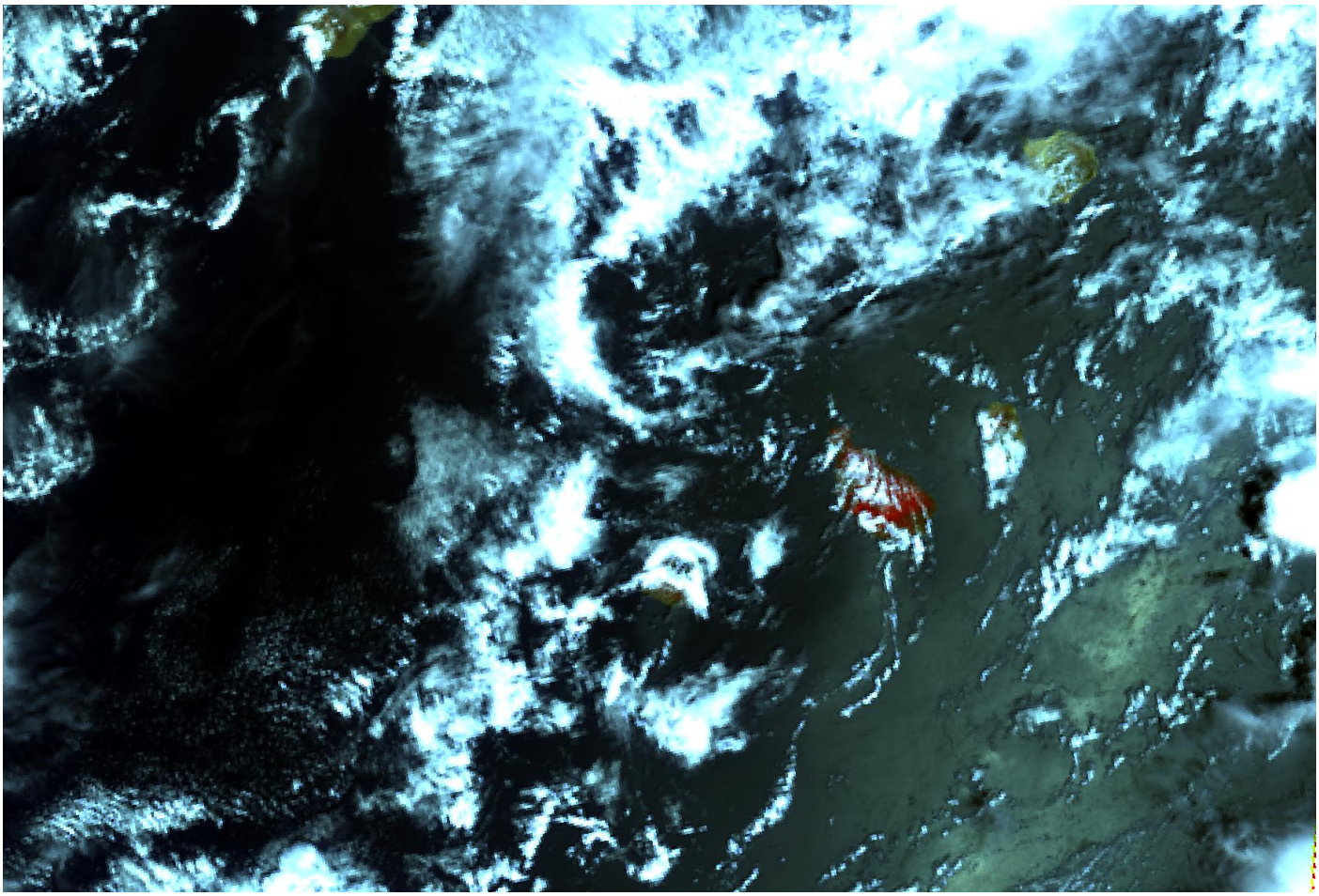


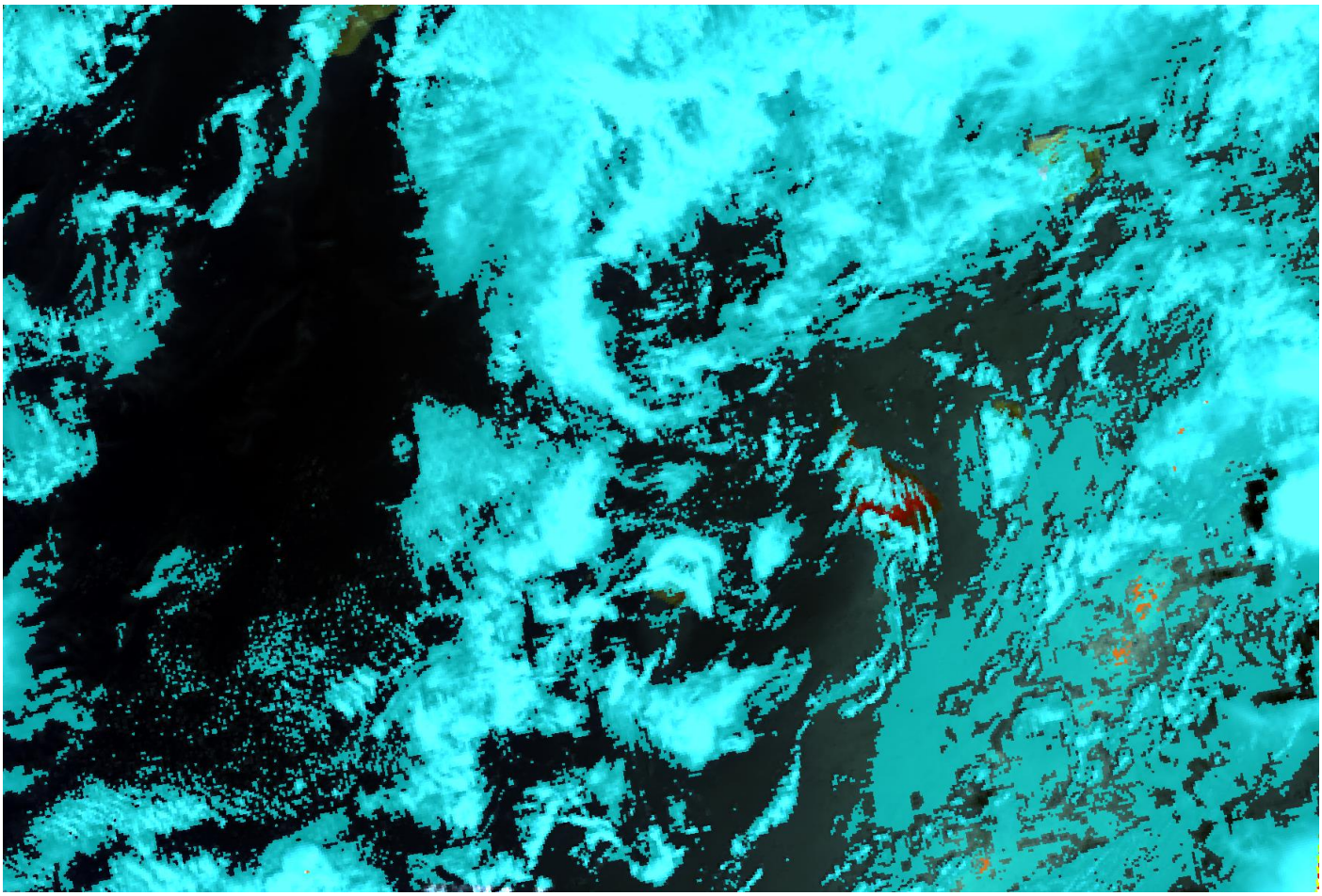
60. The same Fragment (Sahara)

Aerosol pixel are recognized as cloudy, is it correct?



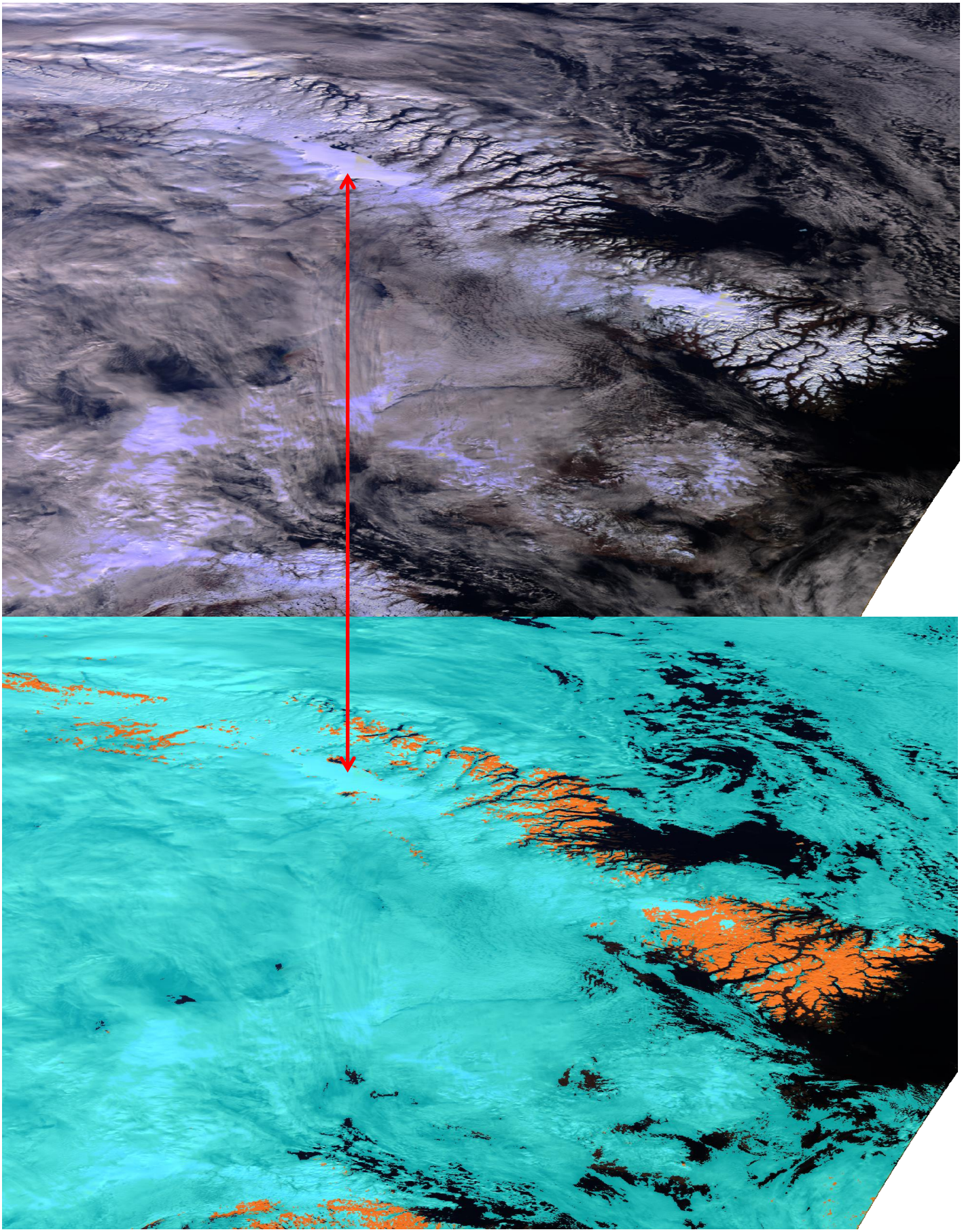
61. PROBAV_L2A_20140621_123717_2_1KM_V103 (East Atlantic, Canarias)
A lot of sun glint pixels (the bottom right corner of the image) are wrong labelled as cloudy (and sometimes even as ice)



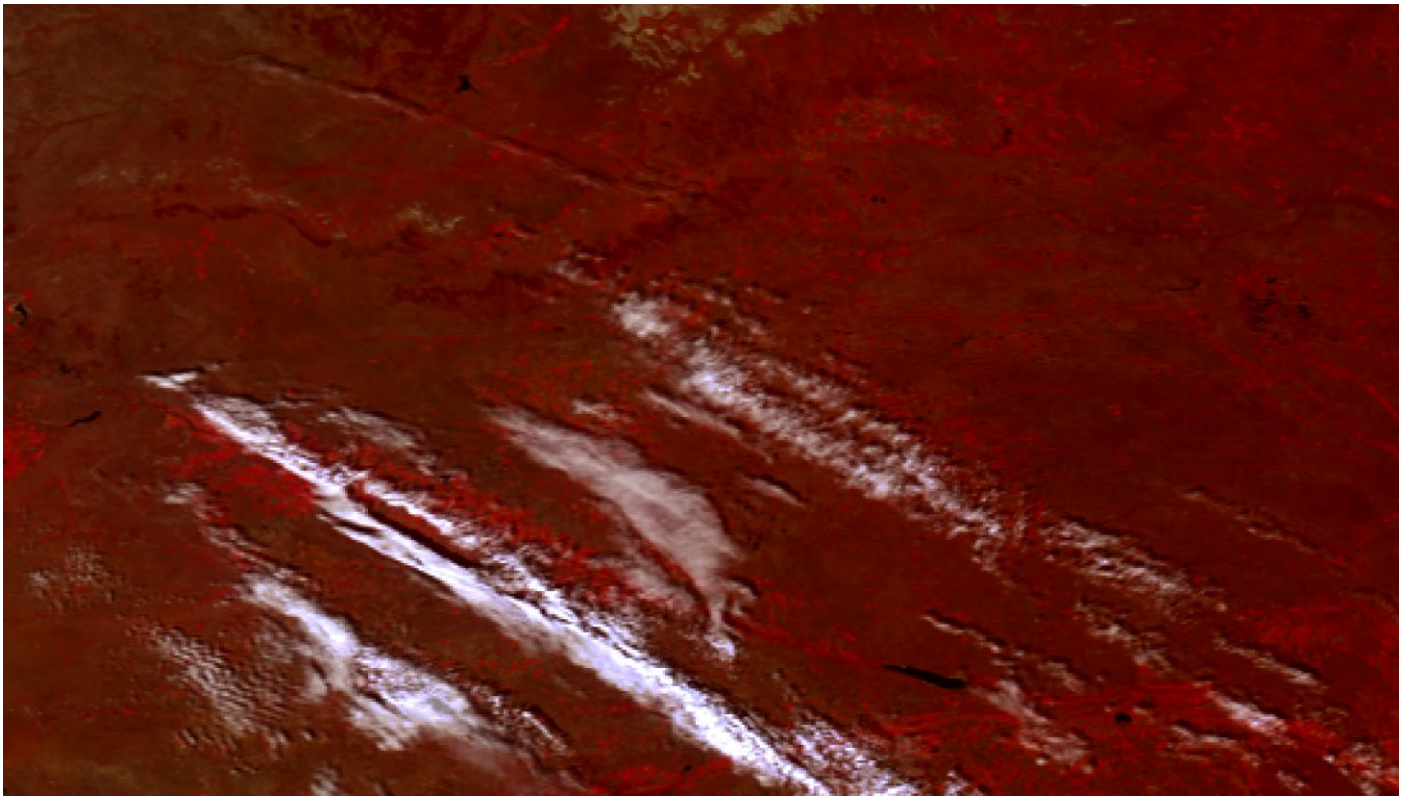


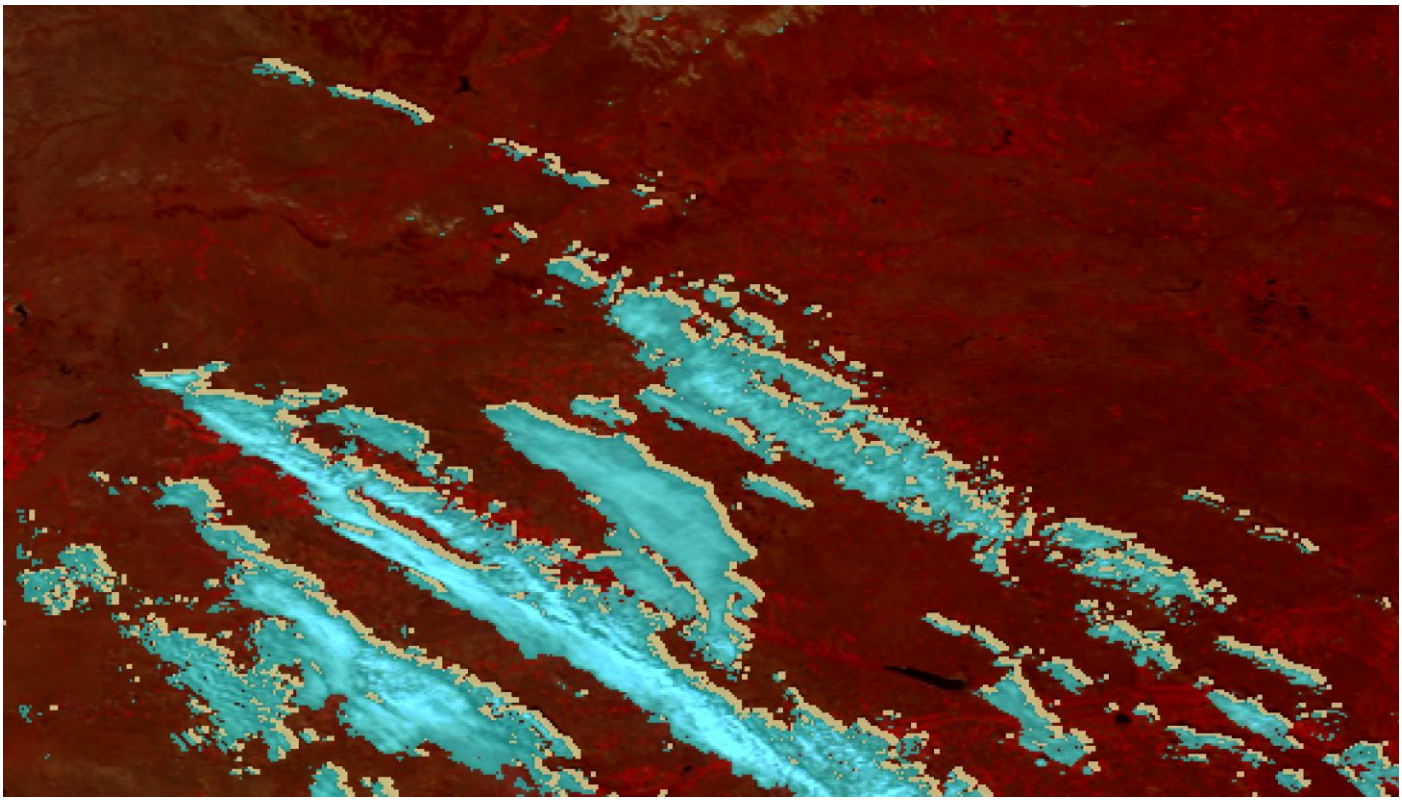
62. PROBAV_L2A_20140621_154245_3_1KM_V103 (Baffin Island)

A lot of clear sky snow/ice covered pixels are erroneous masked as cloudy pixels.



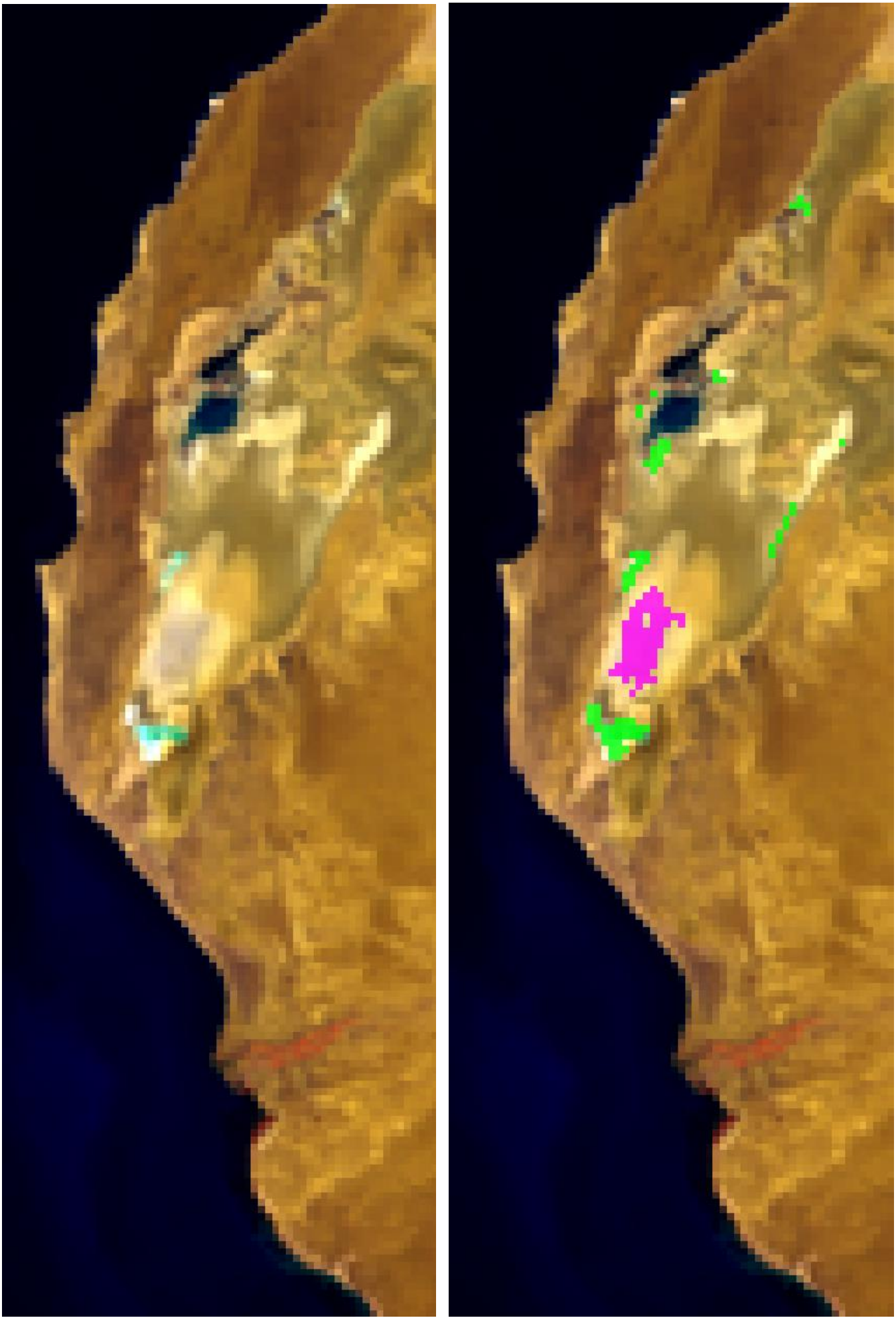
63. PROBAV_L2A_20140621_172401_3_1KM_V103 (South America)
Clouds and shadow - well hit.





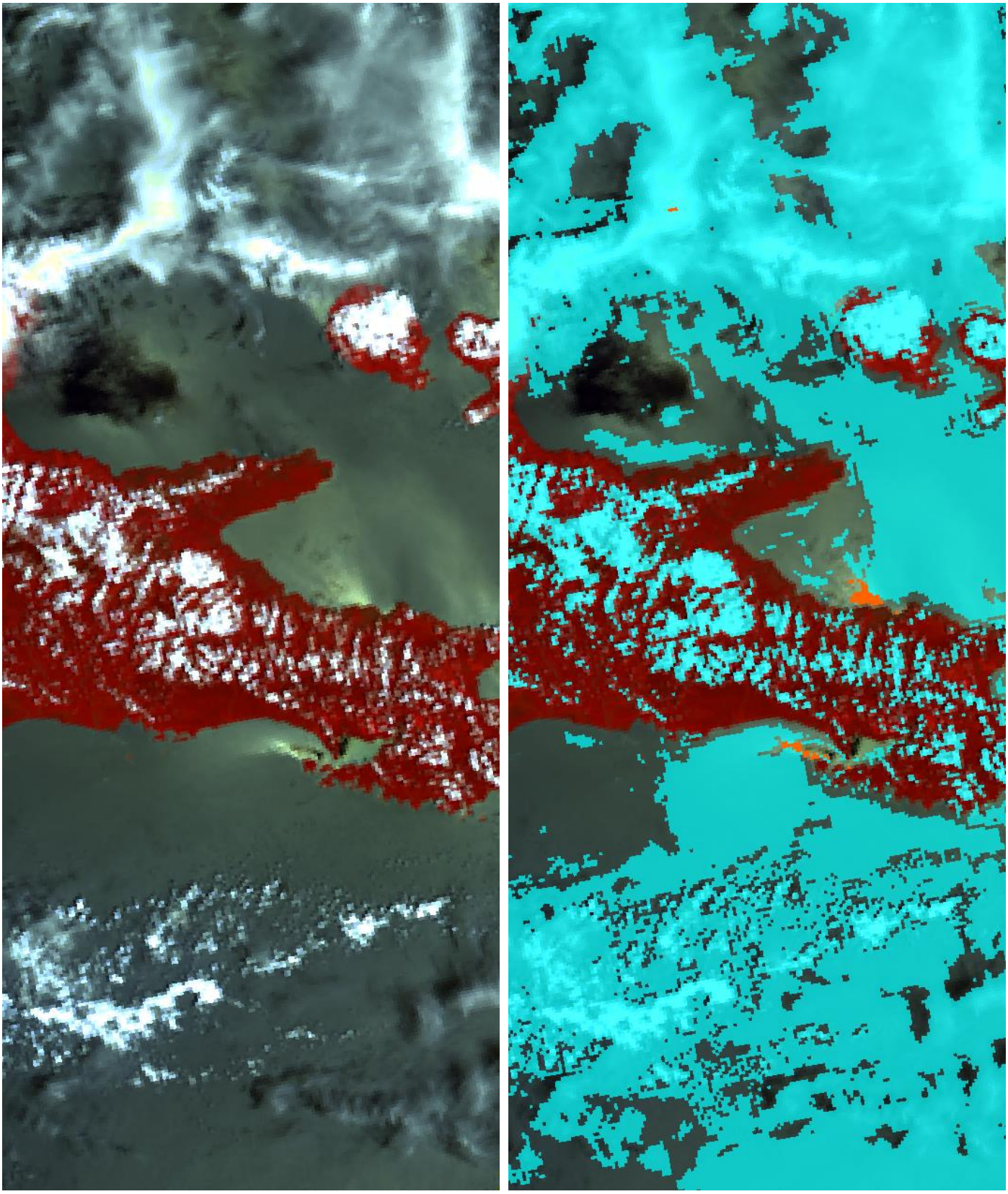
64. PROBAV_L2A_20140621_172401_3_1KM_V103 (West Australia)

Salt, in places dry lakes are wrong labelled as cloudy or icy.

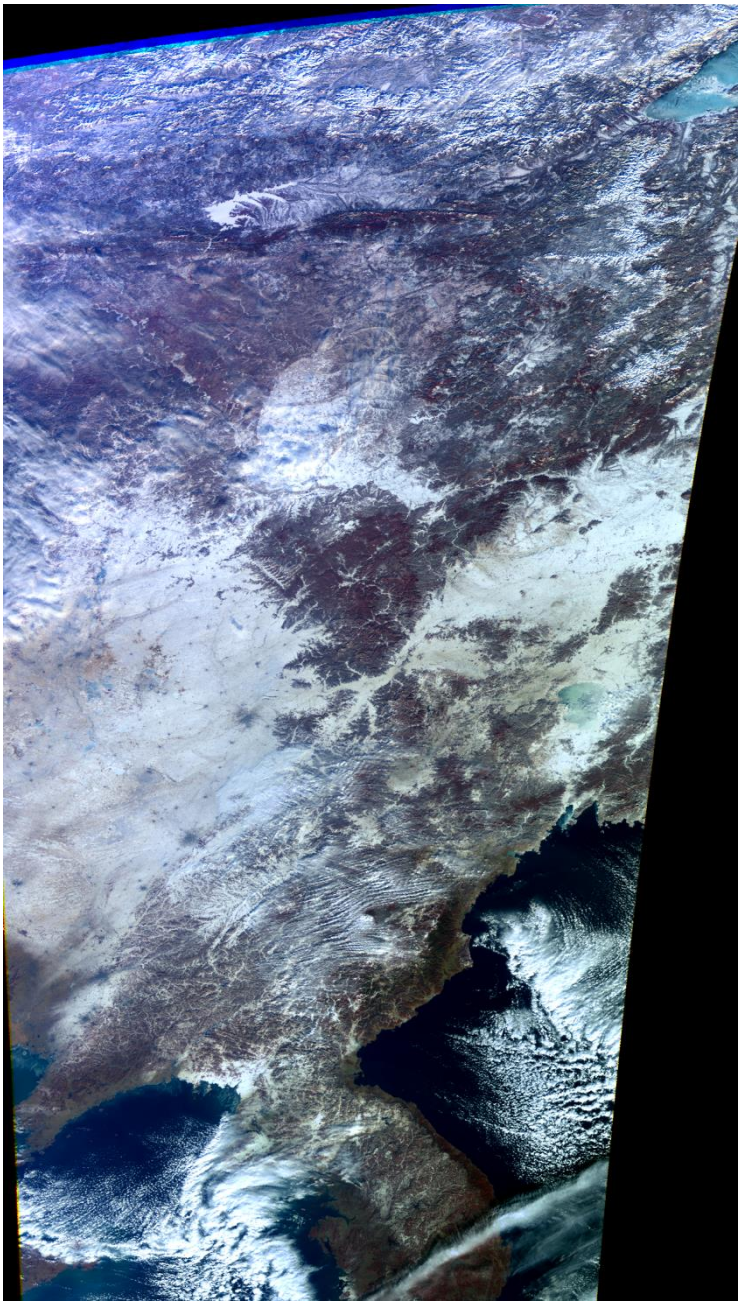


65. PROBAV_L2A_20140621_004943_2_1KM_V103 (Goodenogh Bay, Papua)

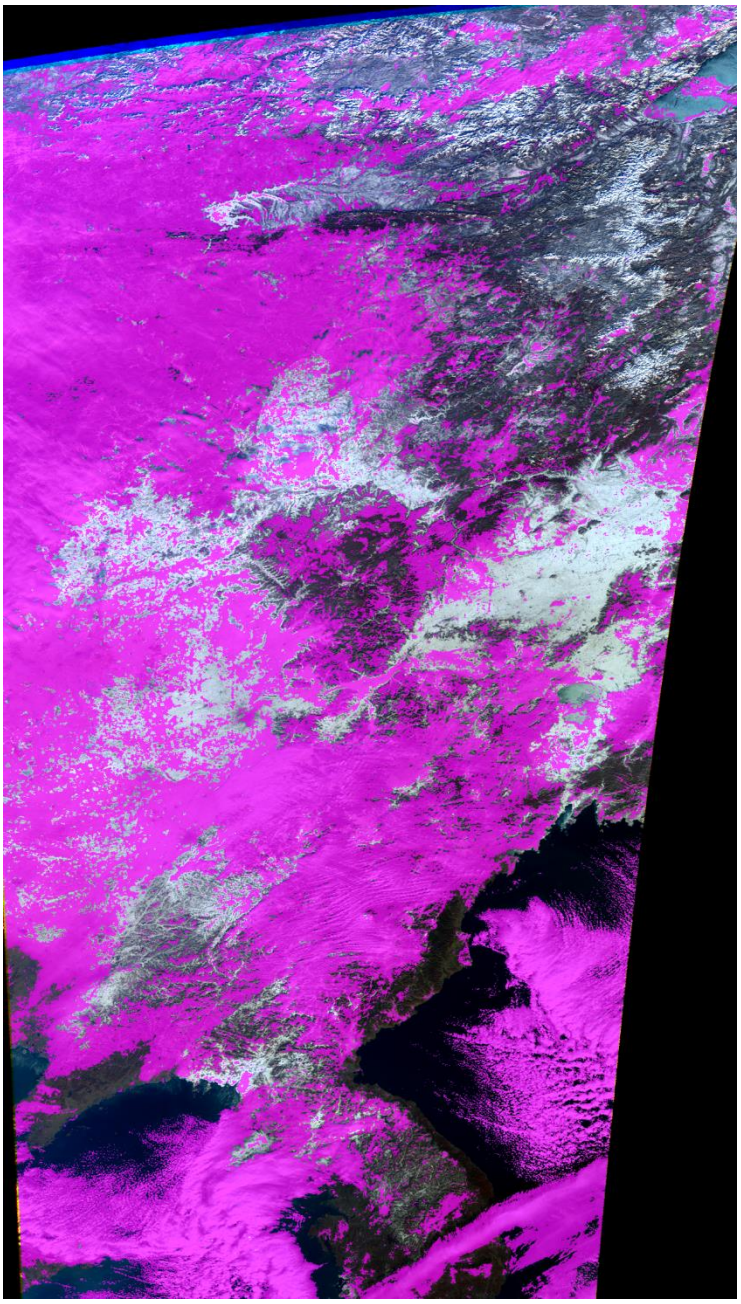
A lot of sun glint pixels are wrong as cloudy or icy (if particularly bright) recognized.



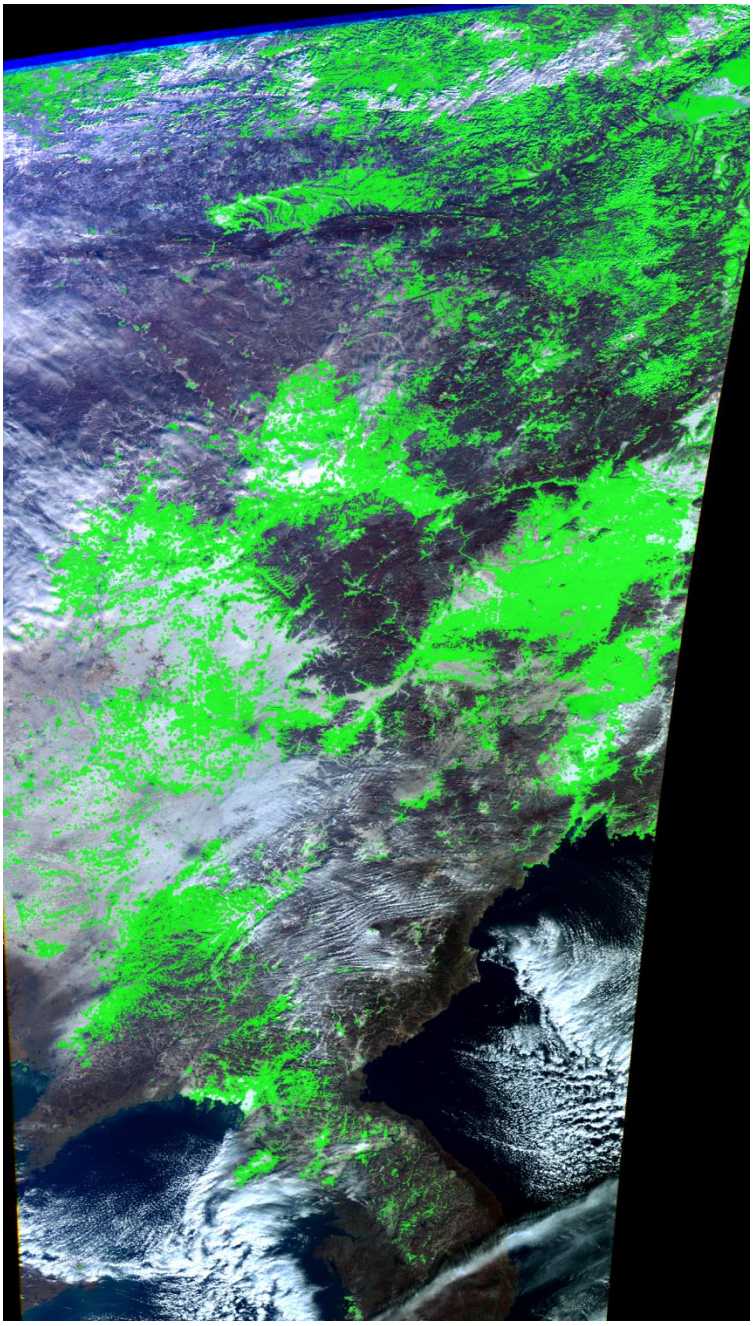
66. PROBAV_L2A_20140621_021446_3_1KM_V103 (Southwest Siberia, North China, Korea)
A well done mask



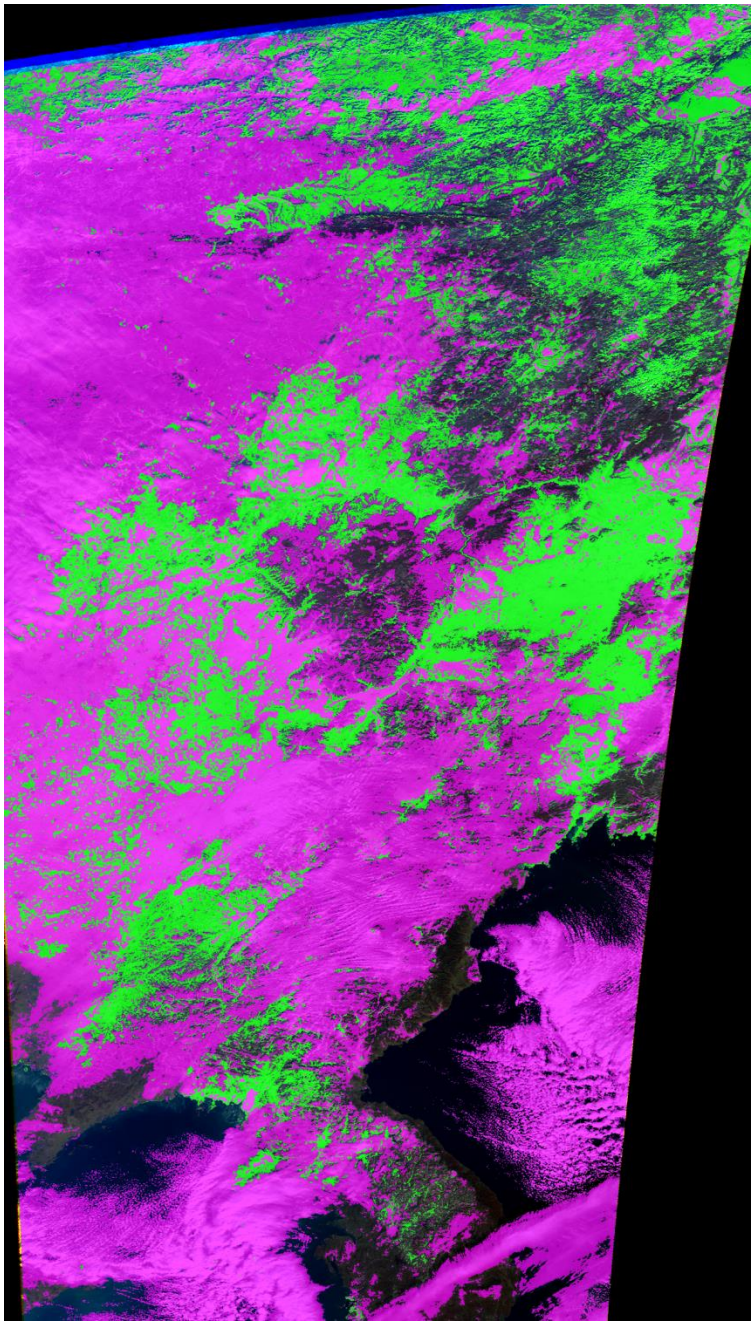
RGB1



Cloud mask



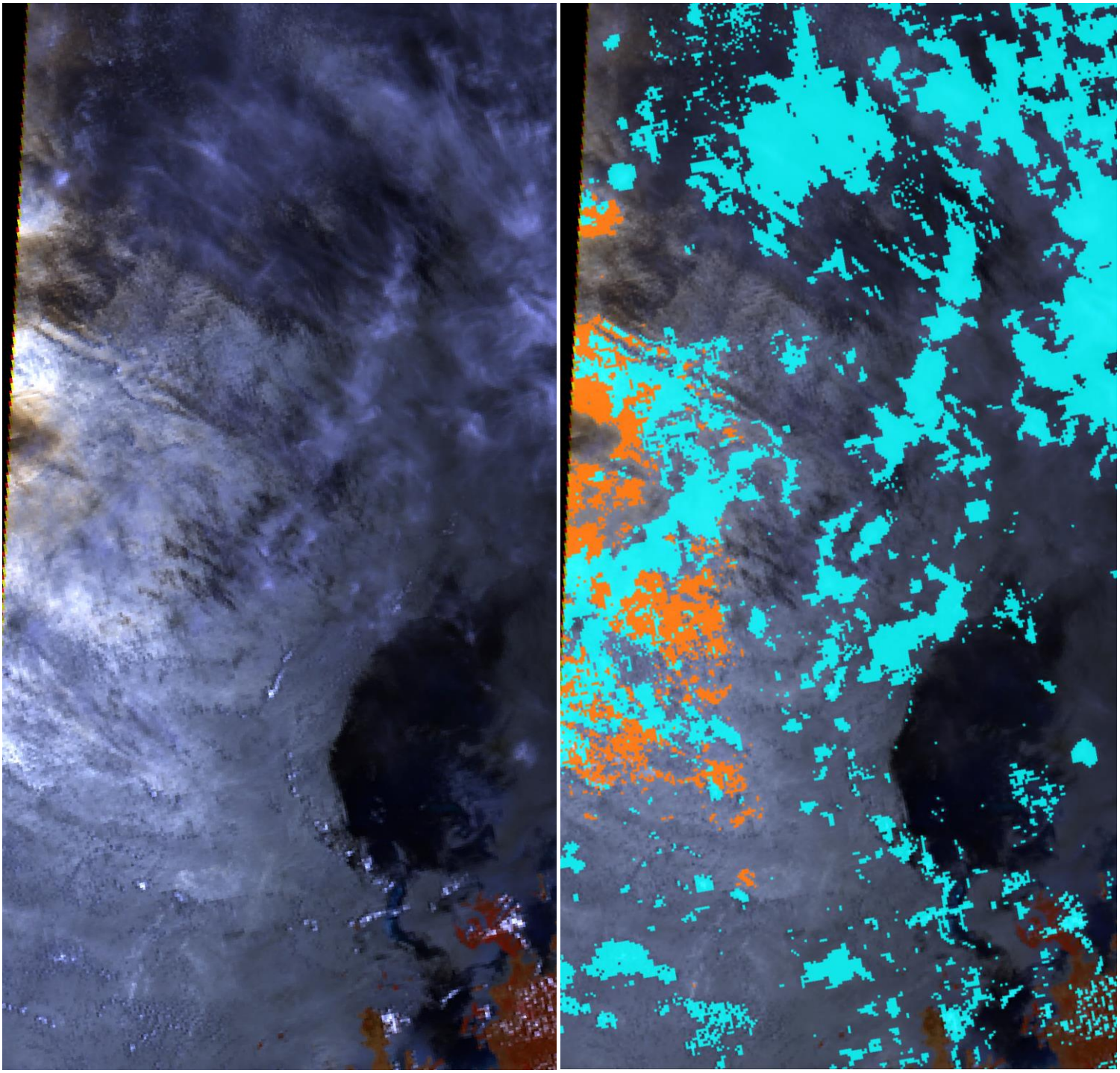
Snow/Ice mask



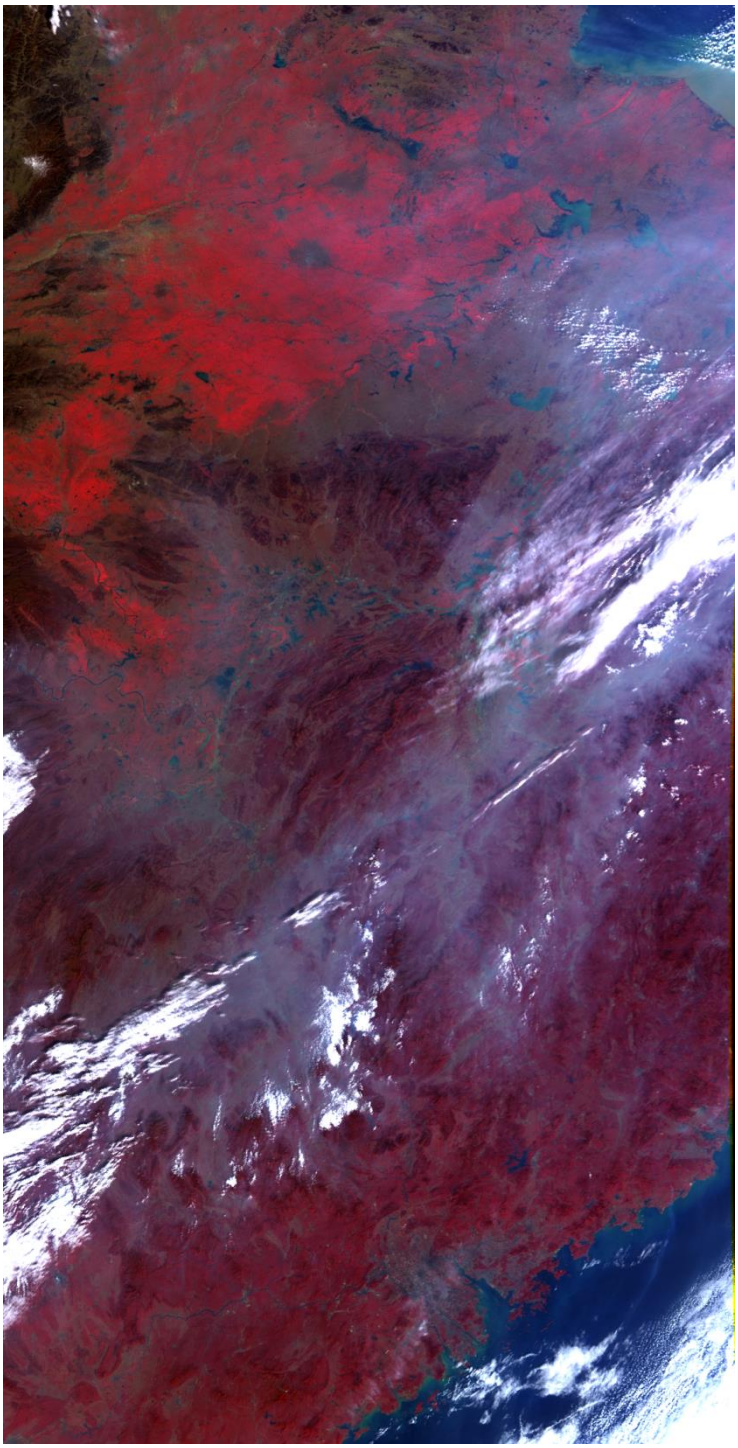
Cloud mask & snow/ice mask

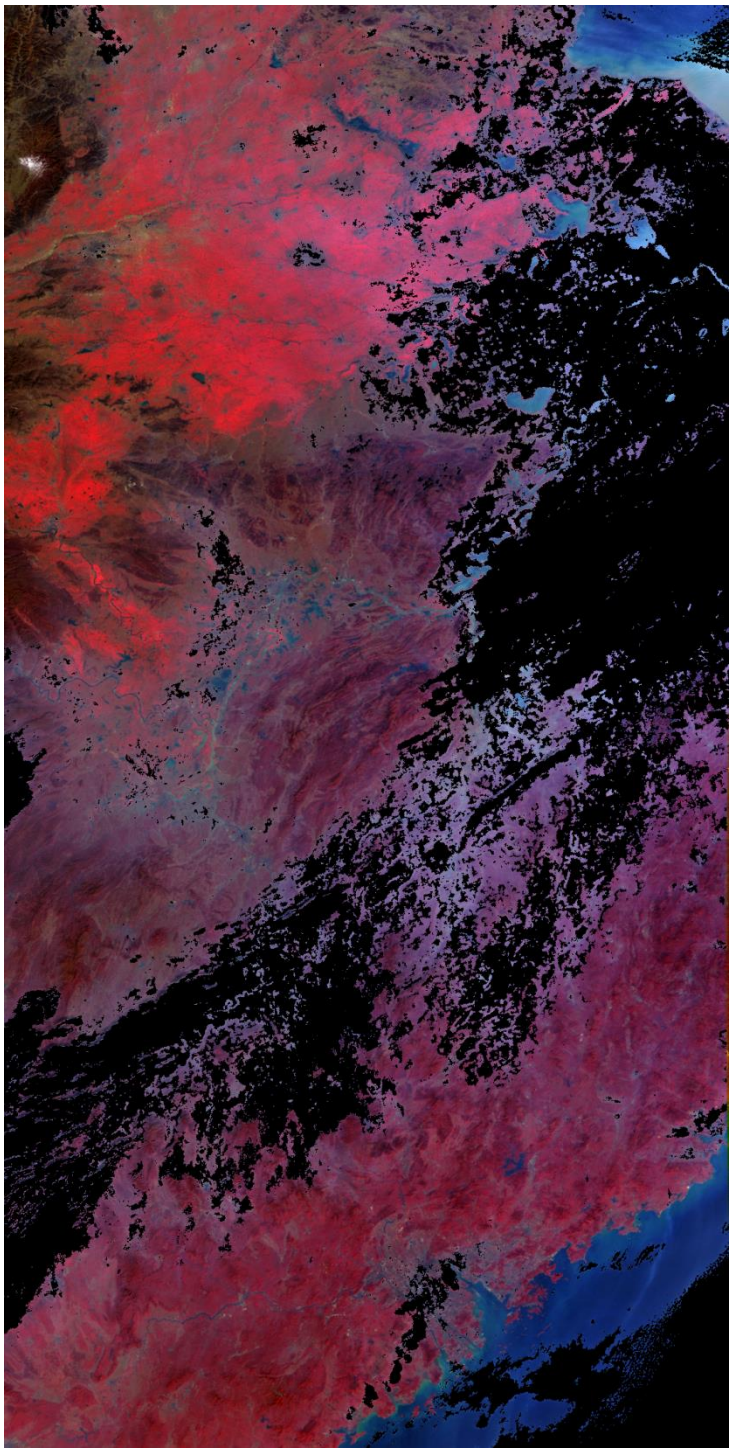
67. PROBAV_L2A_20140621_022940_1_1KM_V103 (Timor Sea)

A lot of sun glint pixels are wrong as cloudy or icy (if particularly bright) recognized.

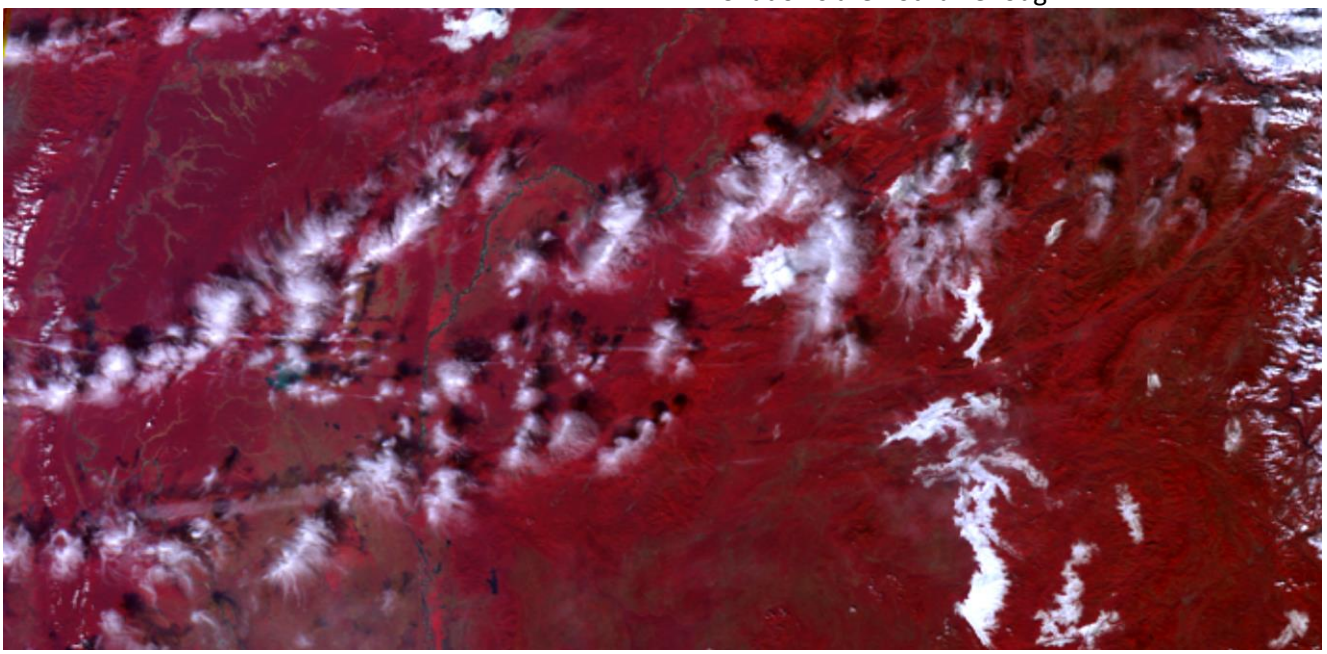


68. PROBAV_L2A_20140621_035559_1_1KM_V103 (China between Henan and Guangdong)
Fog, haze have been well captured.
Very thin fog remained undetected.
The cloud mask is exceptionally **black.**

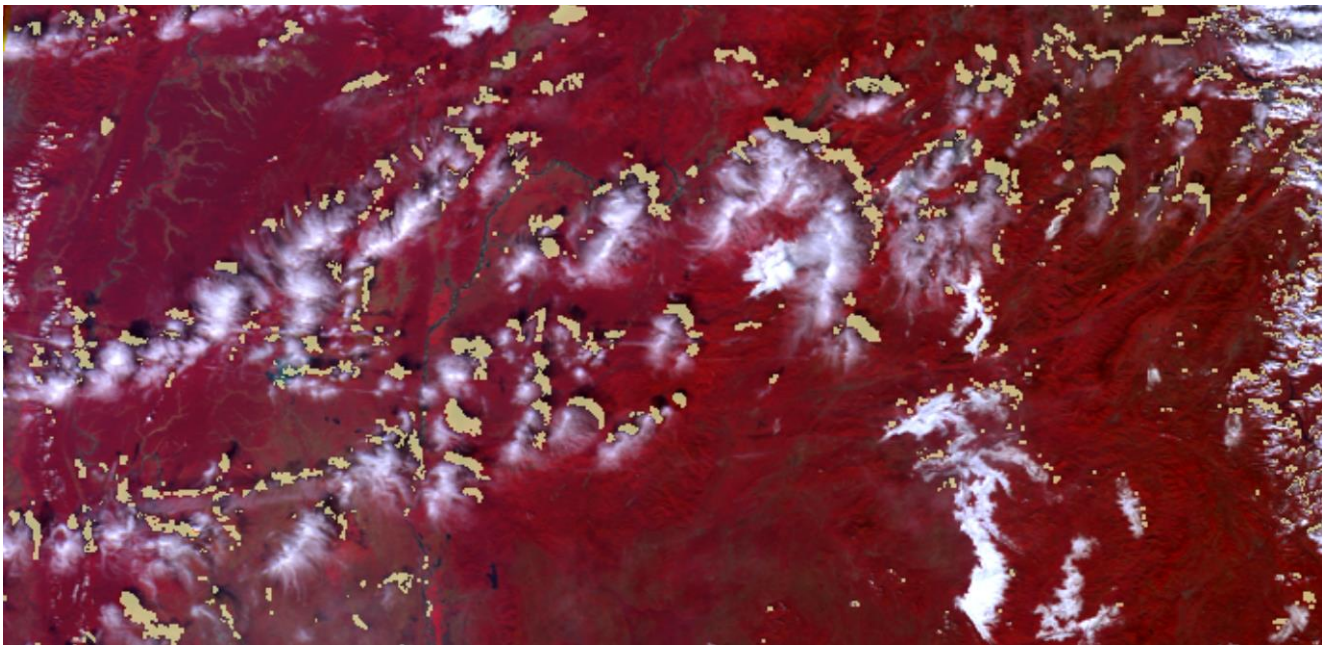




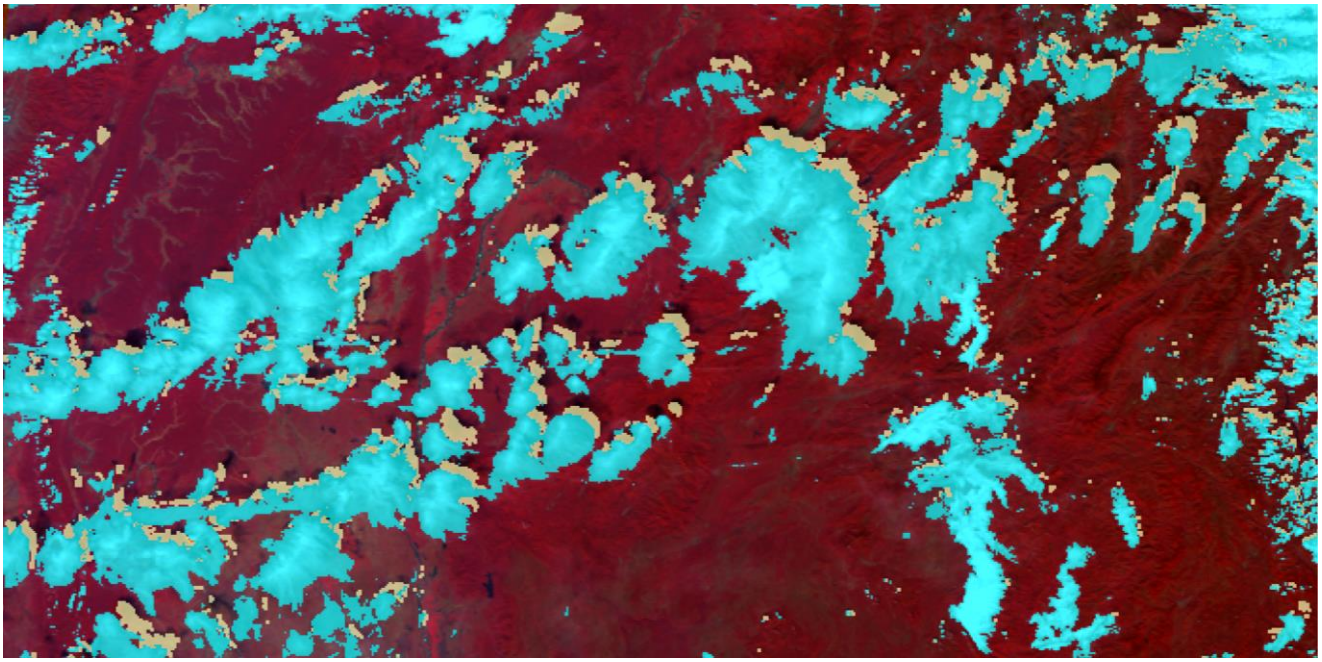
69. PROBAV_L2A_20140621_035603_3_1KM_V103 (Assam, Myanmar)
Shadows are not full enough



RGB1

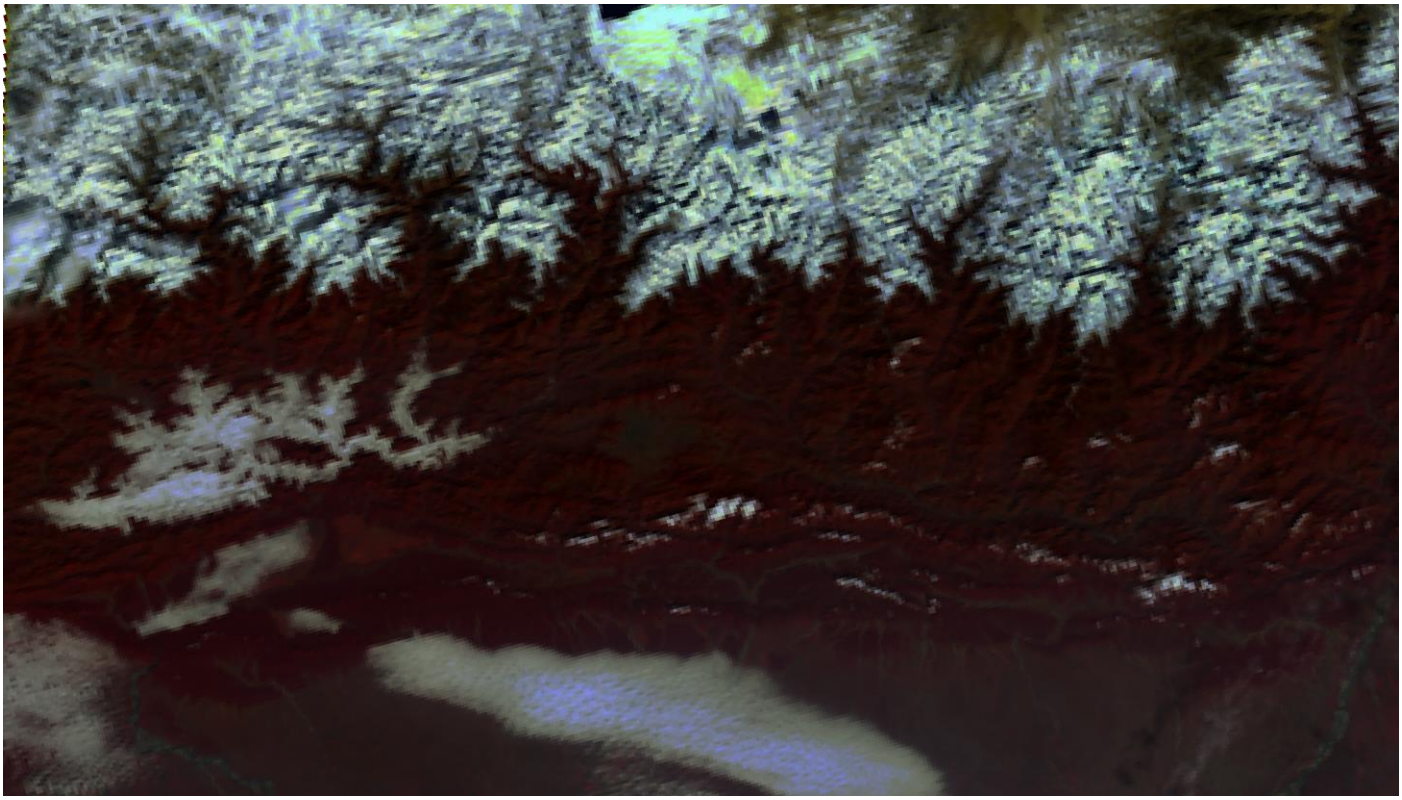


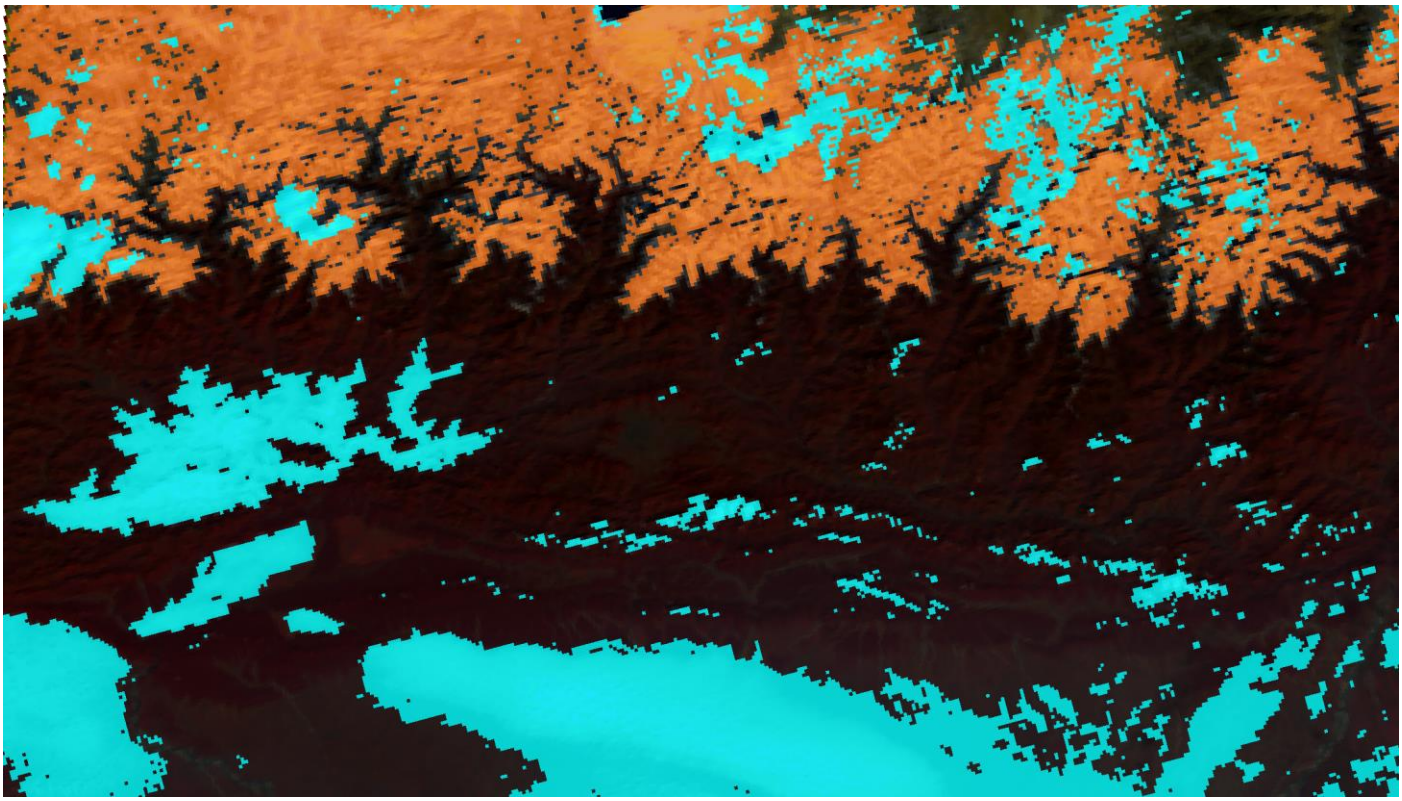
shadow



clouds

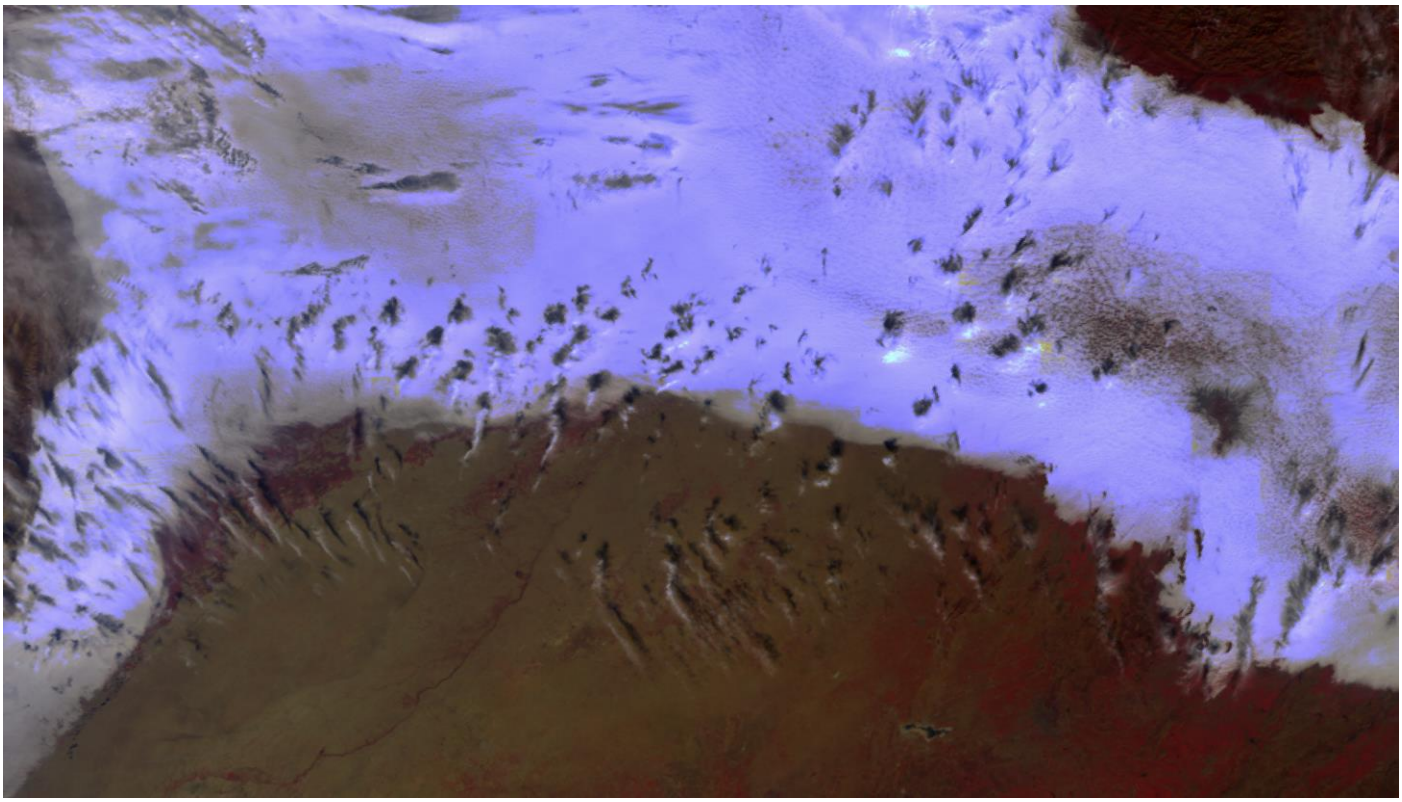
70. PROBAV_L2A_20140621_053714_1_1KM_V103 (Nepal)
Well distinguished snow from fog and clouds.

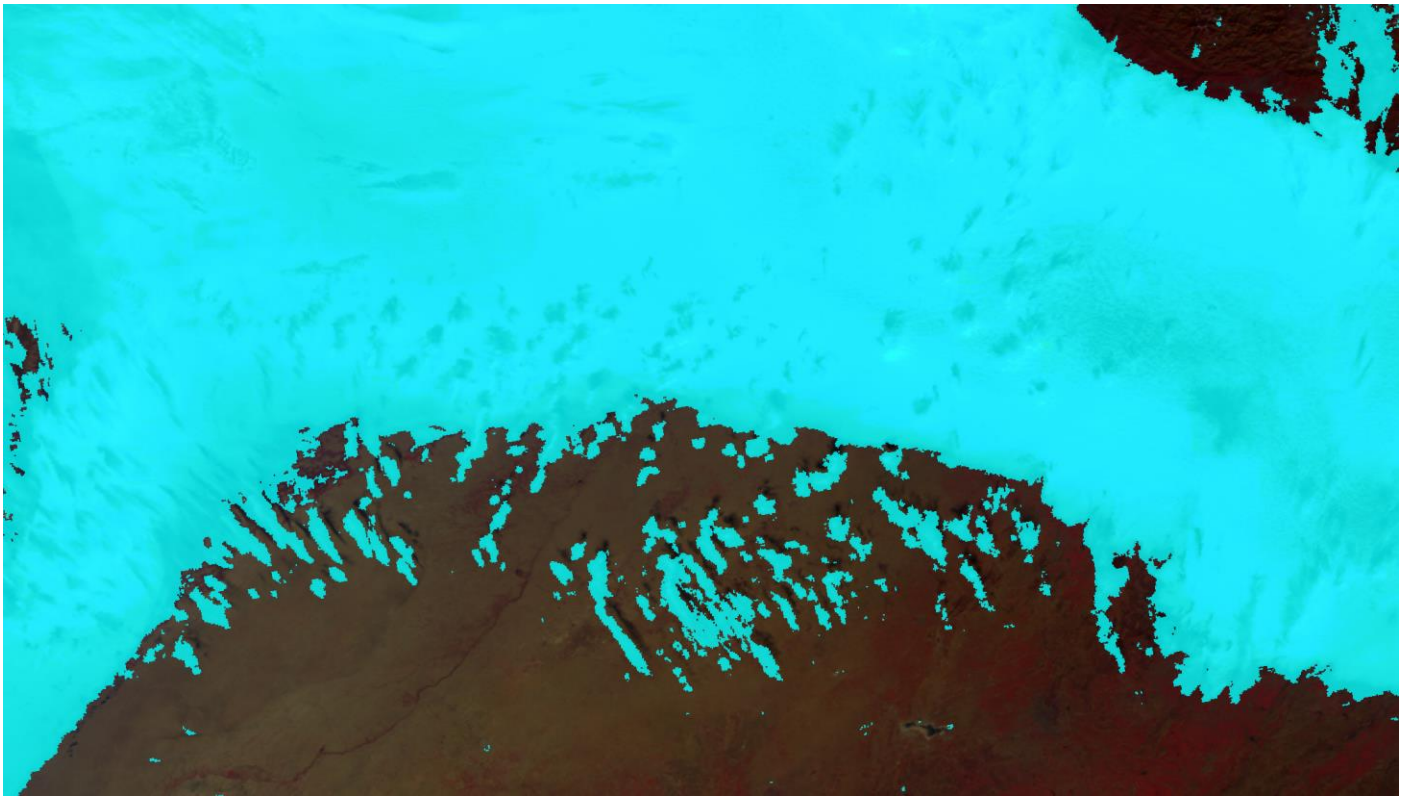




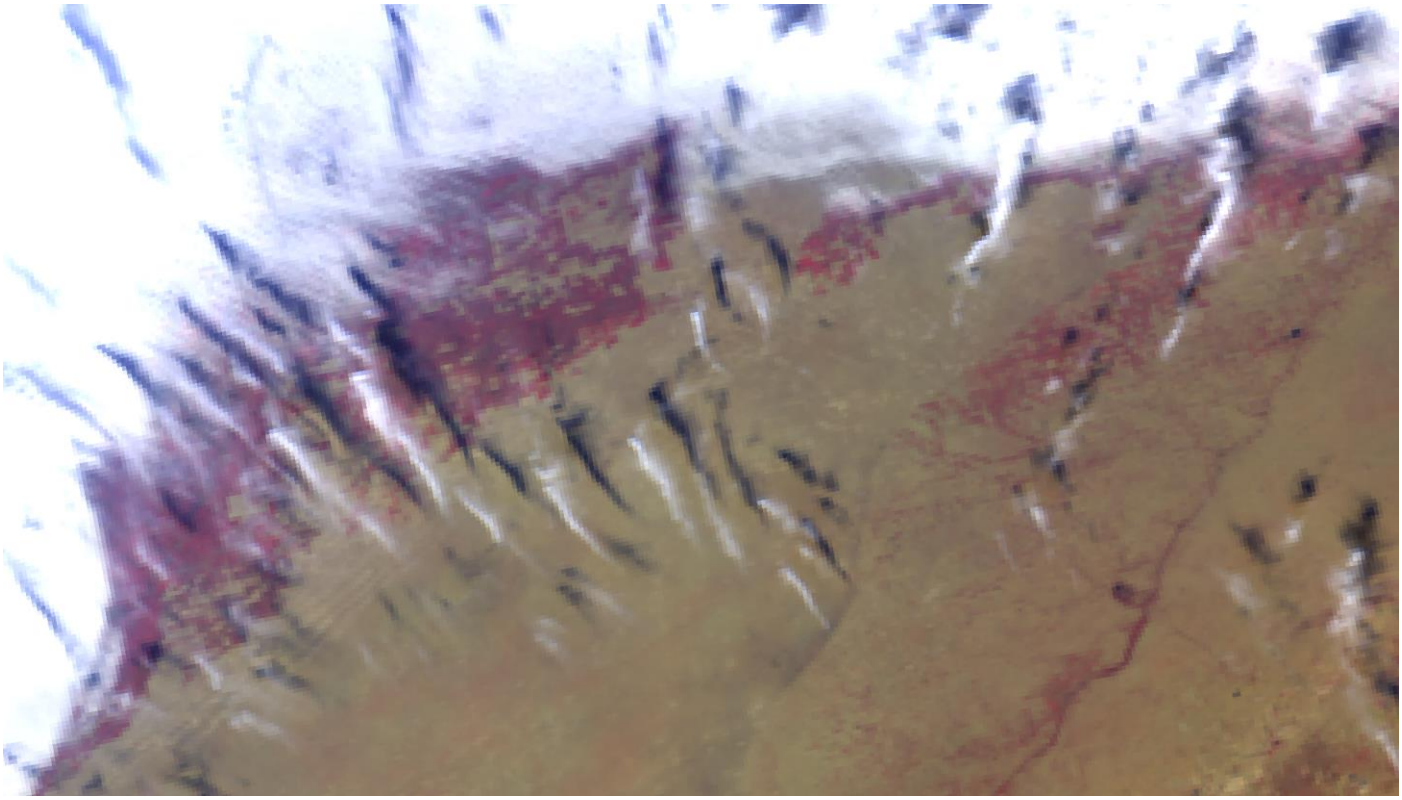
71. PROBAV_L2A_20140621_053718_3_1KM_V103 (North India)

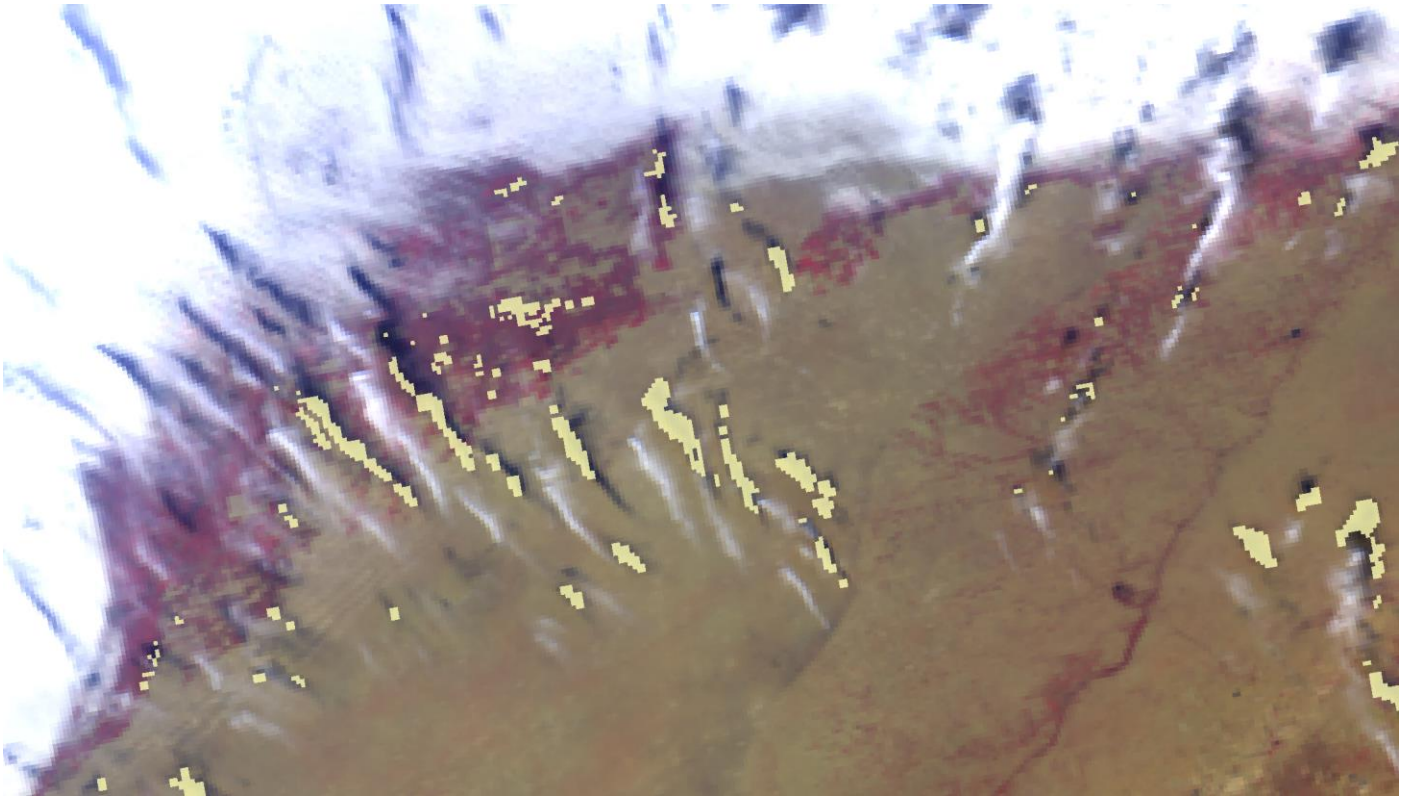
It was managed to prevent from being irritated by very dark shadows above the cloud layer. Really very good cloud recognition.



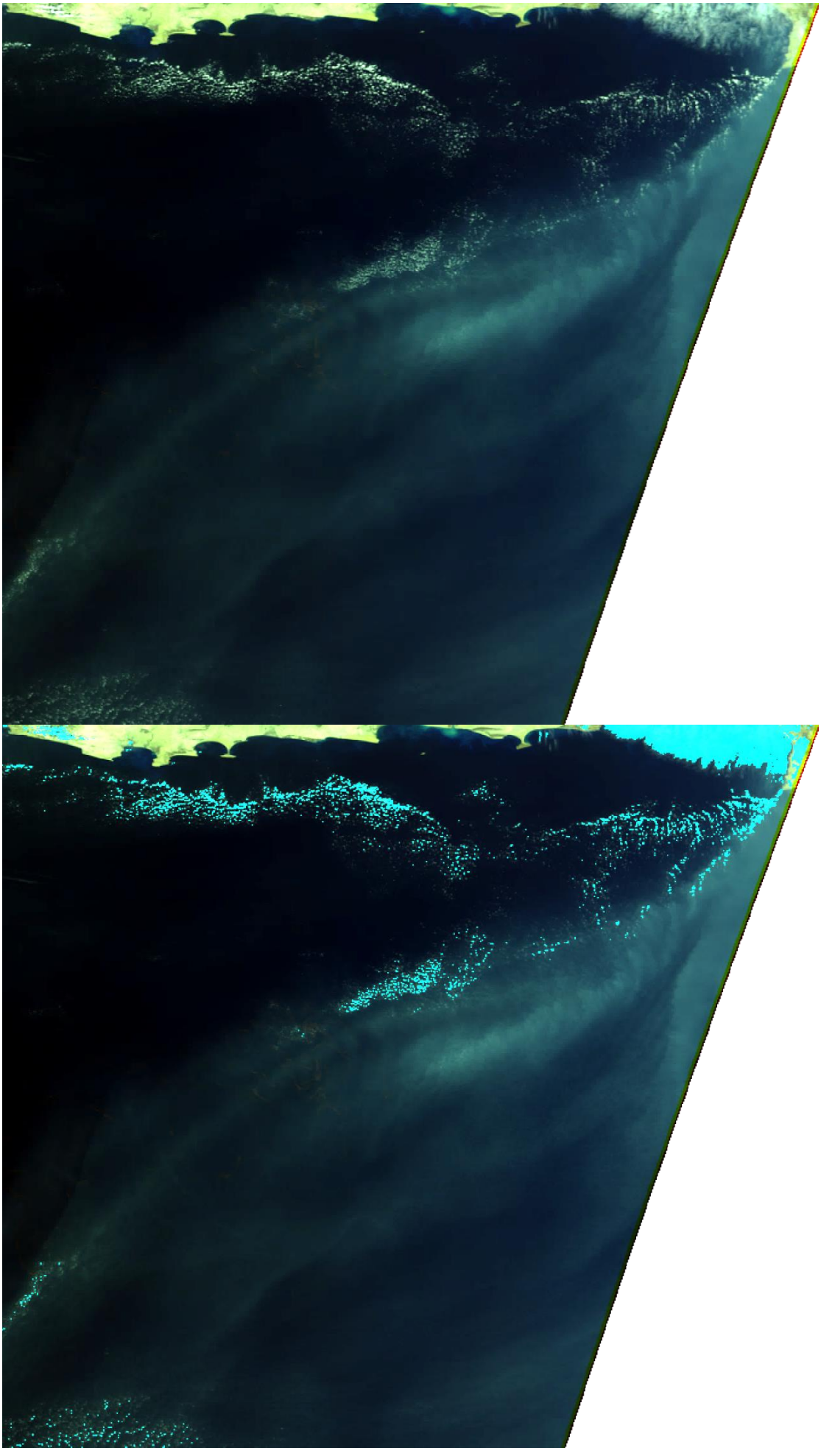


72. The same Fragment (zoomed)
Cloud shadows are recognized not very successfully



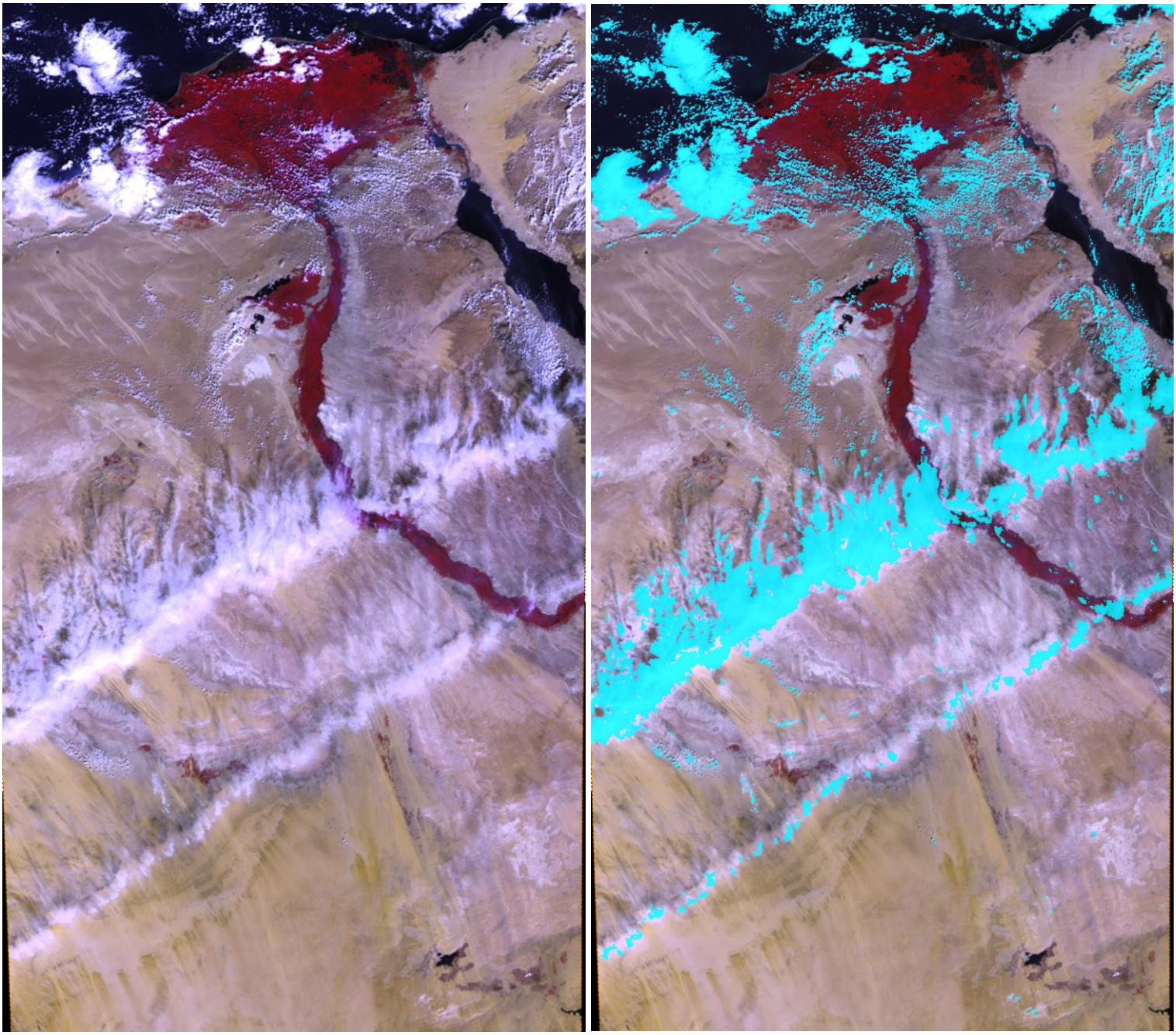


73. PROBAV_L2A_20140621_071829_1_1KM_V103 (Arabian Sea)
Semi-transparent clouds are not labelled completely

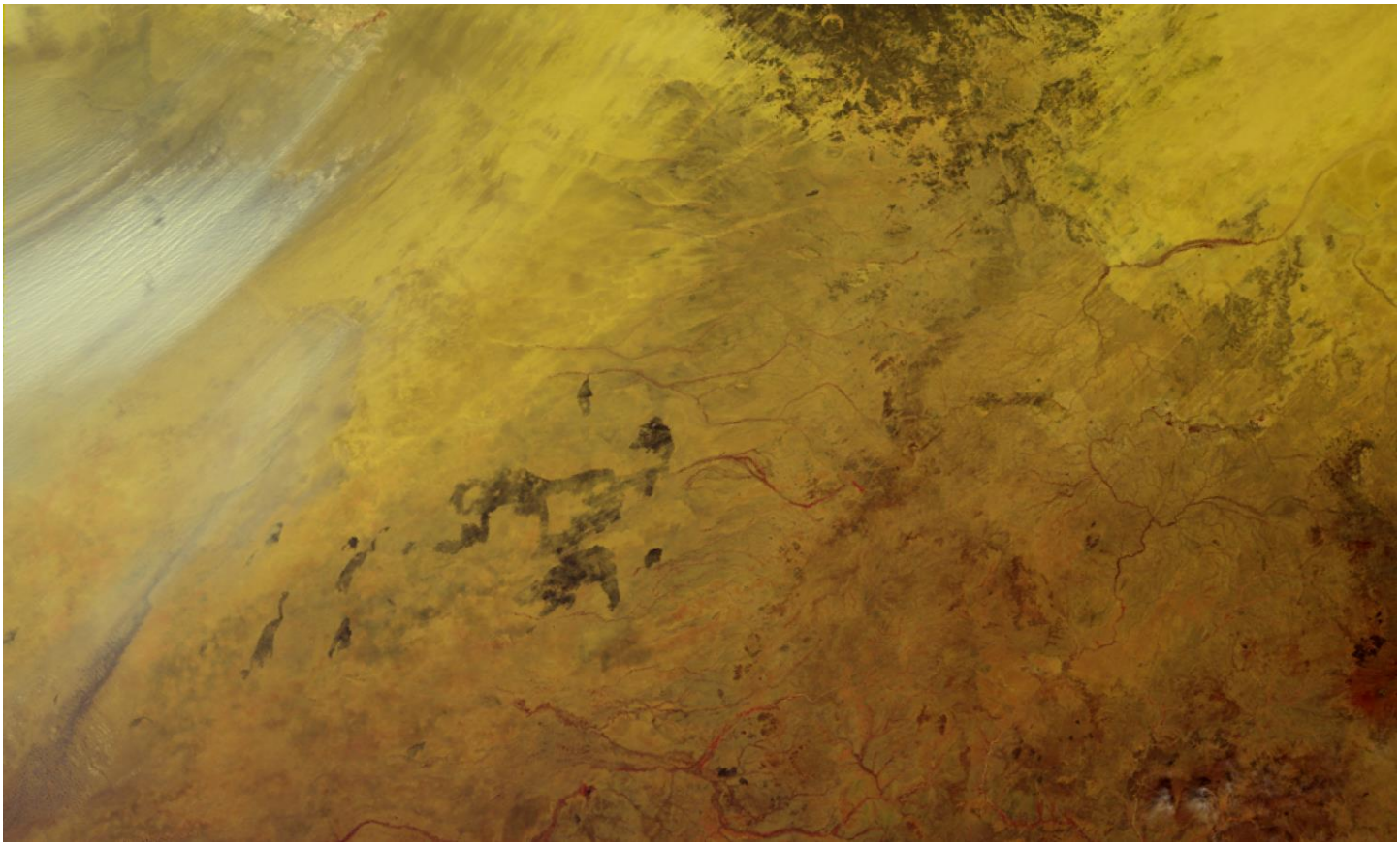


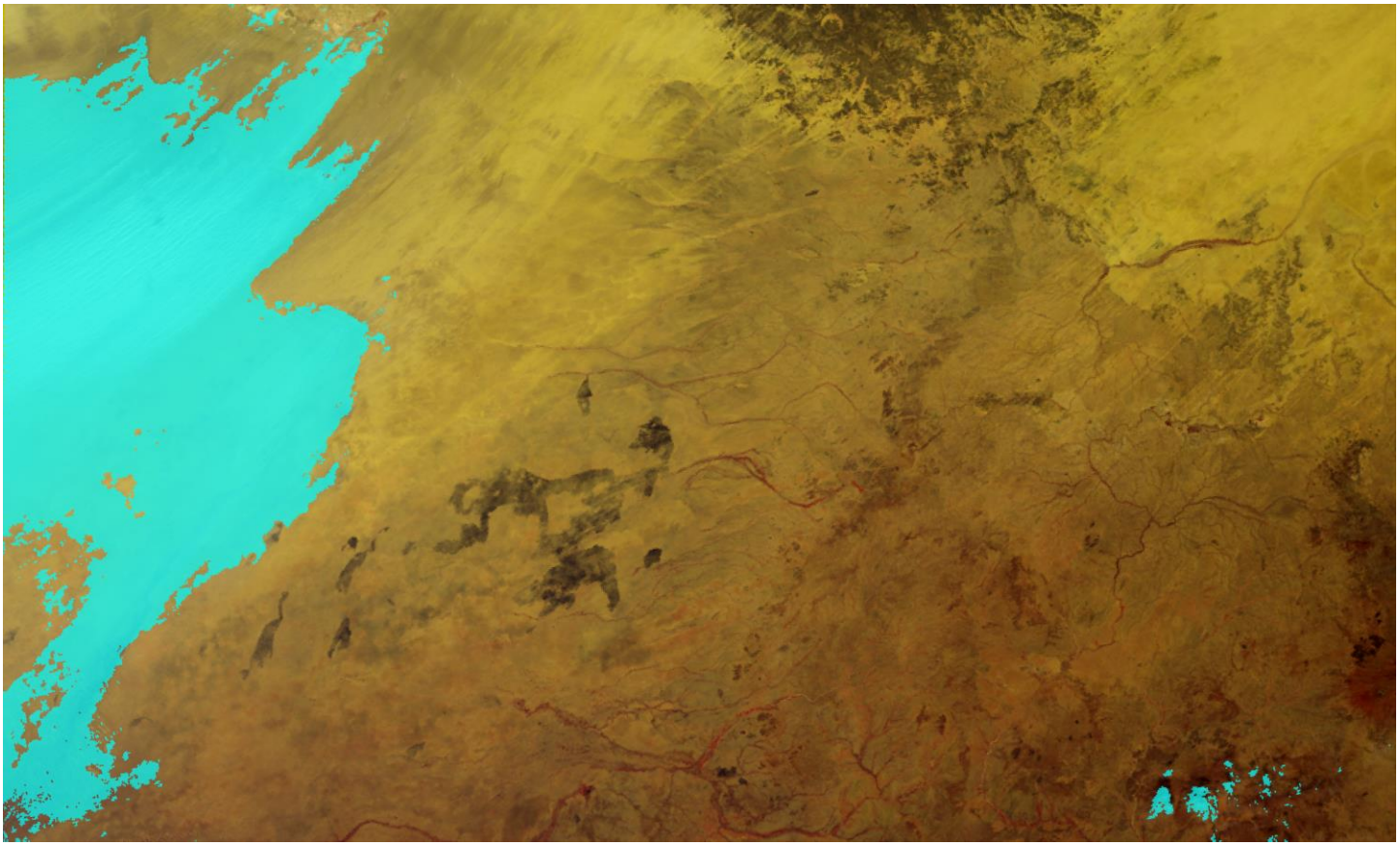
74. PROBAV_L2A_20140621_085947_2_1KM_V103 (Egypt)

A lot of semi-transparent clouds are not marked

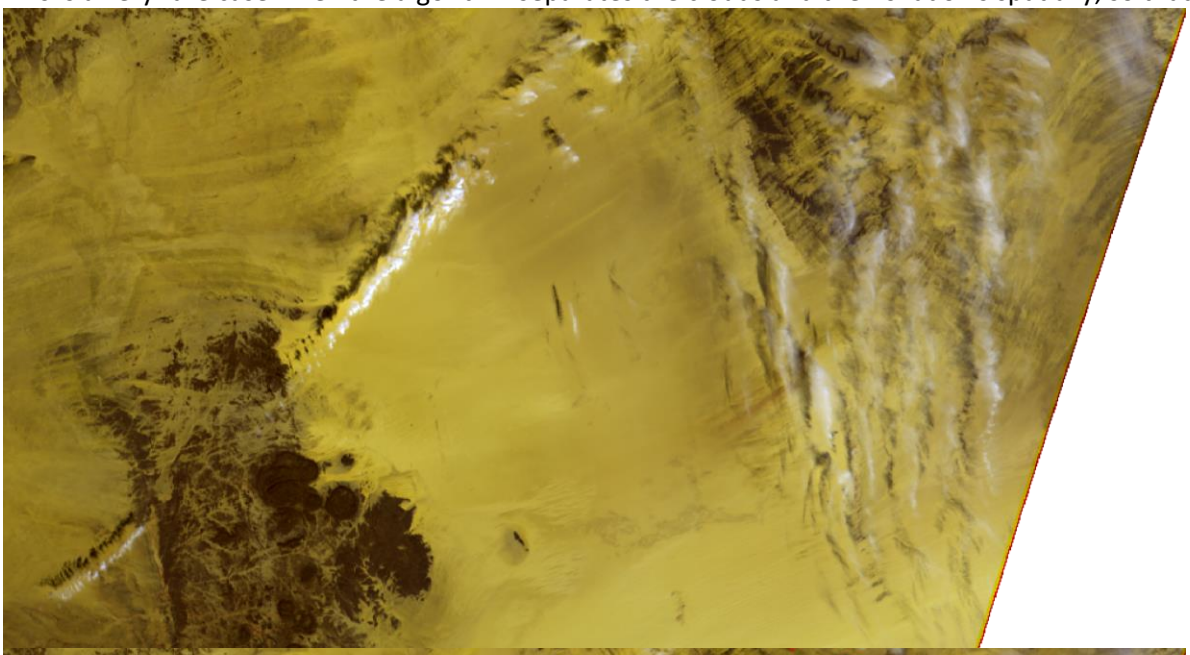


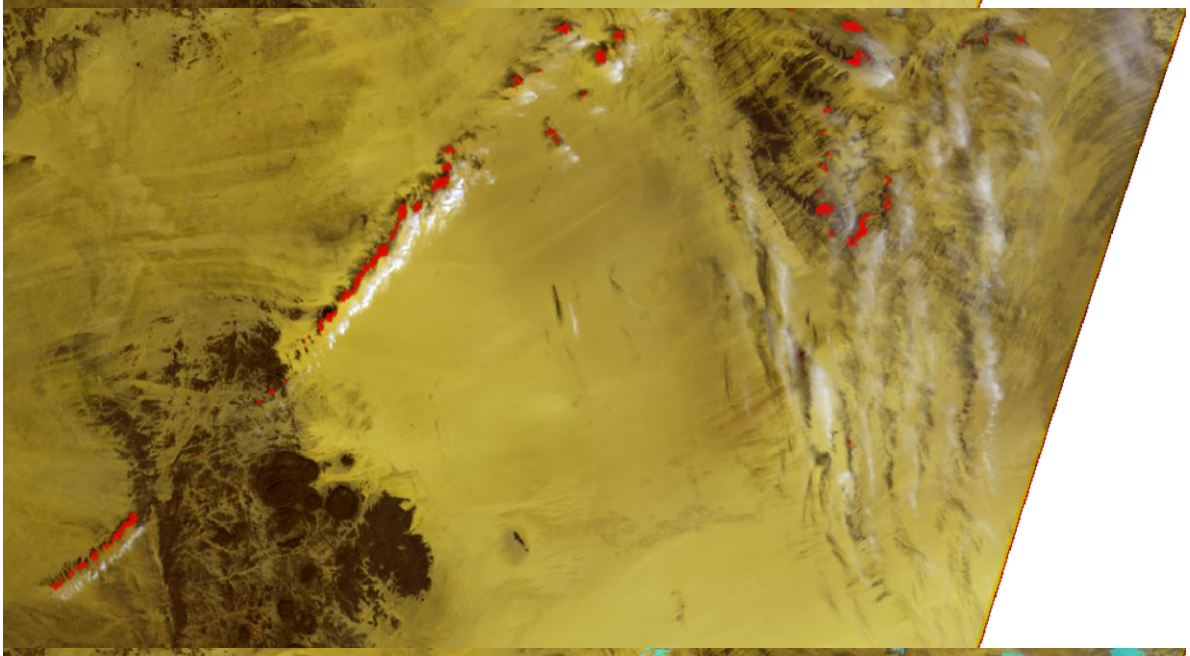
75. PROBAV_L2A_20140621_085949_3_1KM_V103 (Sahara)
Sand storm is erroneously misunderstood as cloud layer

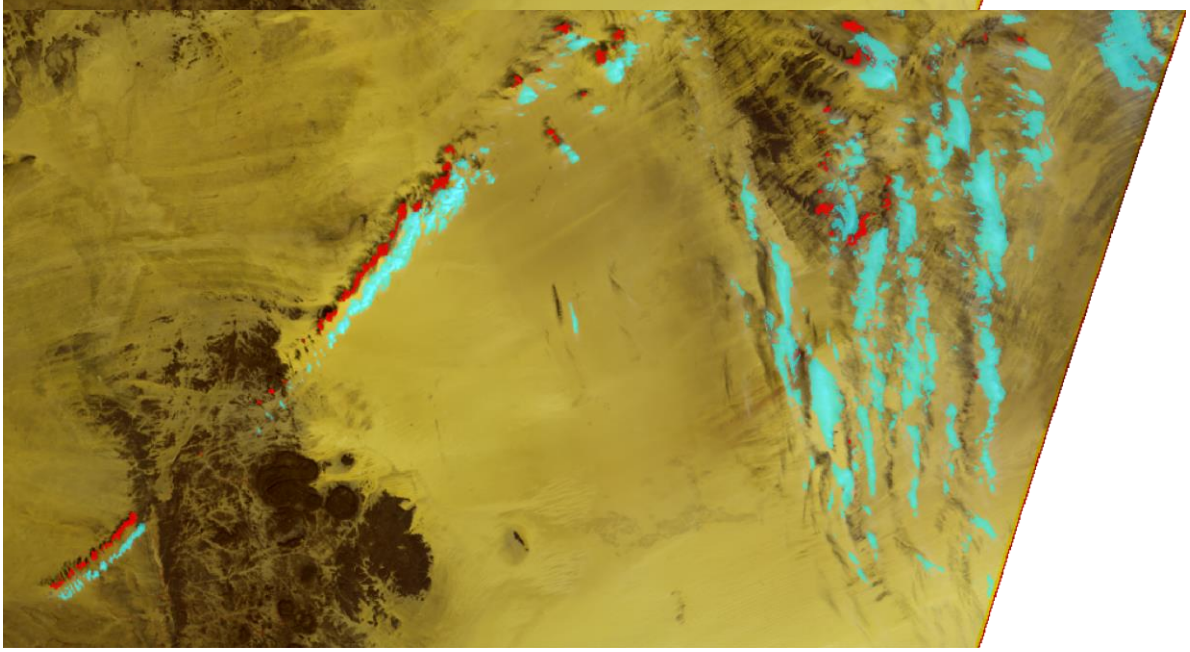




76. PROBAV_L2A_20140621_104101_1_1KM_V103 (West Sahara)
Cloud shadows are not labelled completely
Semi-transparent clouds are labelled sensible enough
This is a very rare case when the algorithm separates the clouds and their shadows spatially, so that they do not touch.

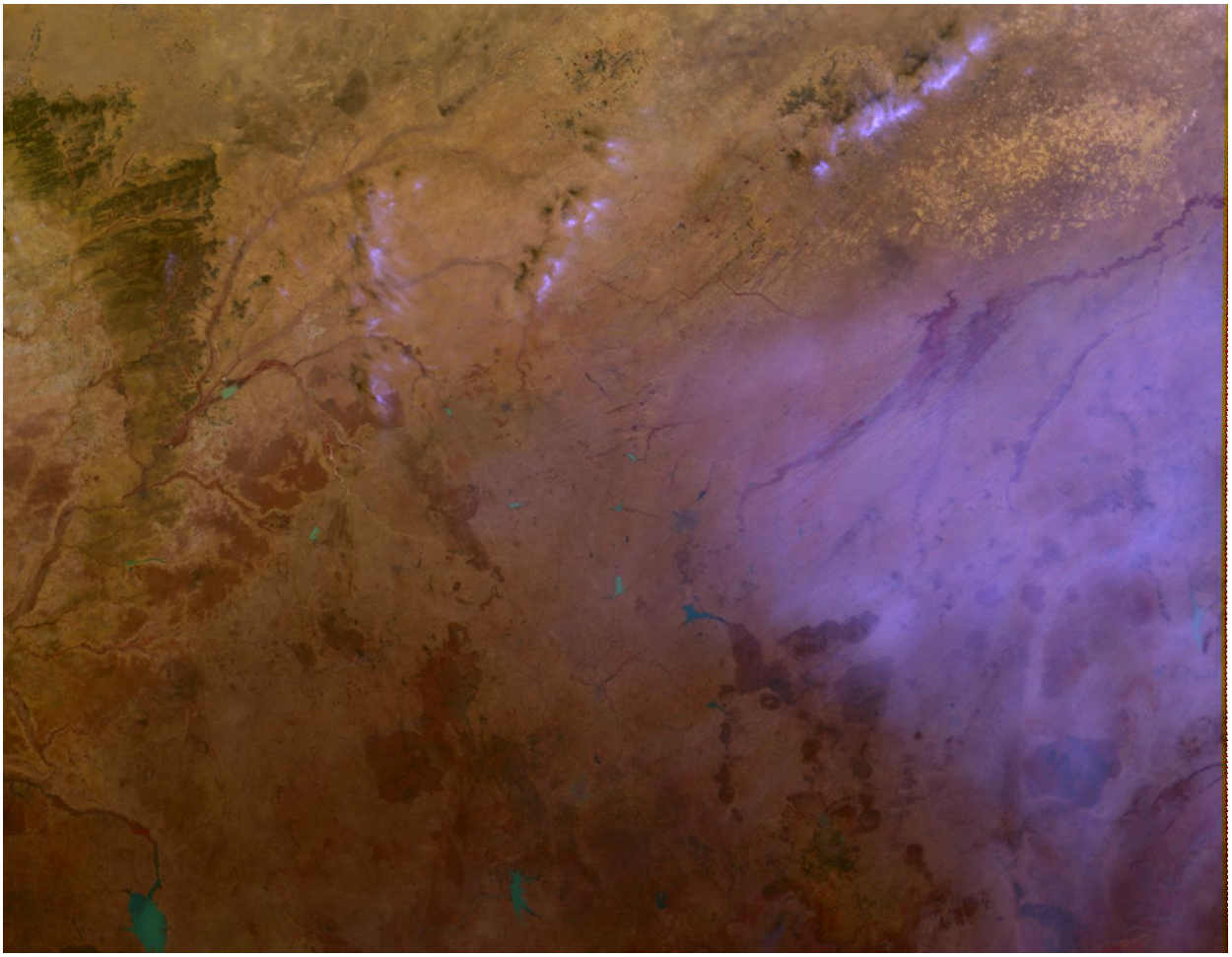


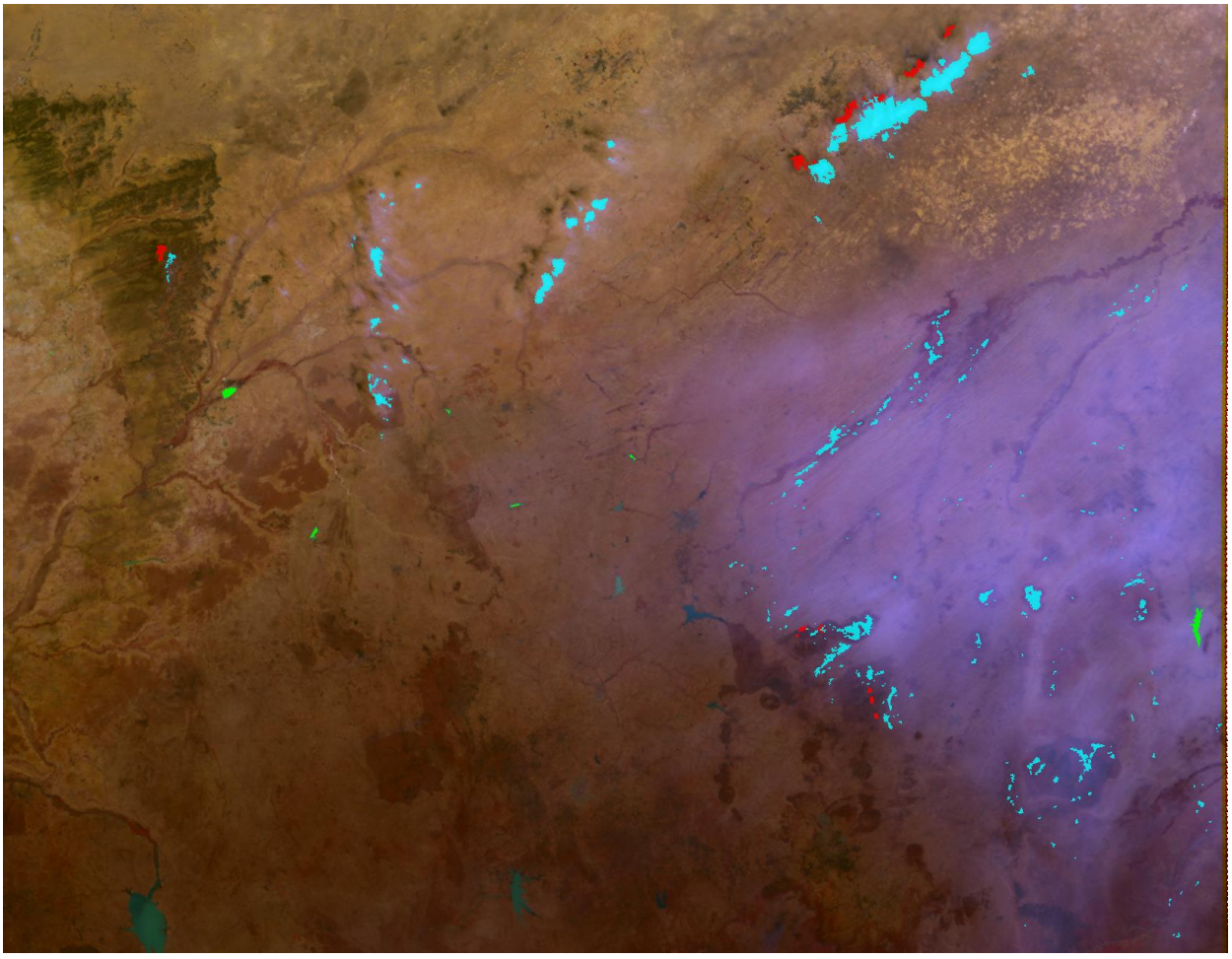




77. The same Fragment

A large territory covered with the very thin haze remained unrecognized

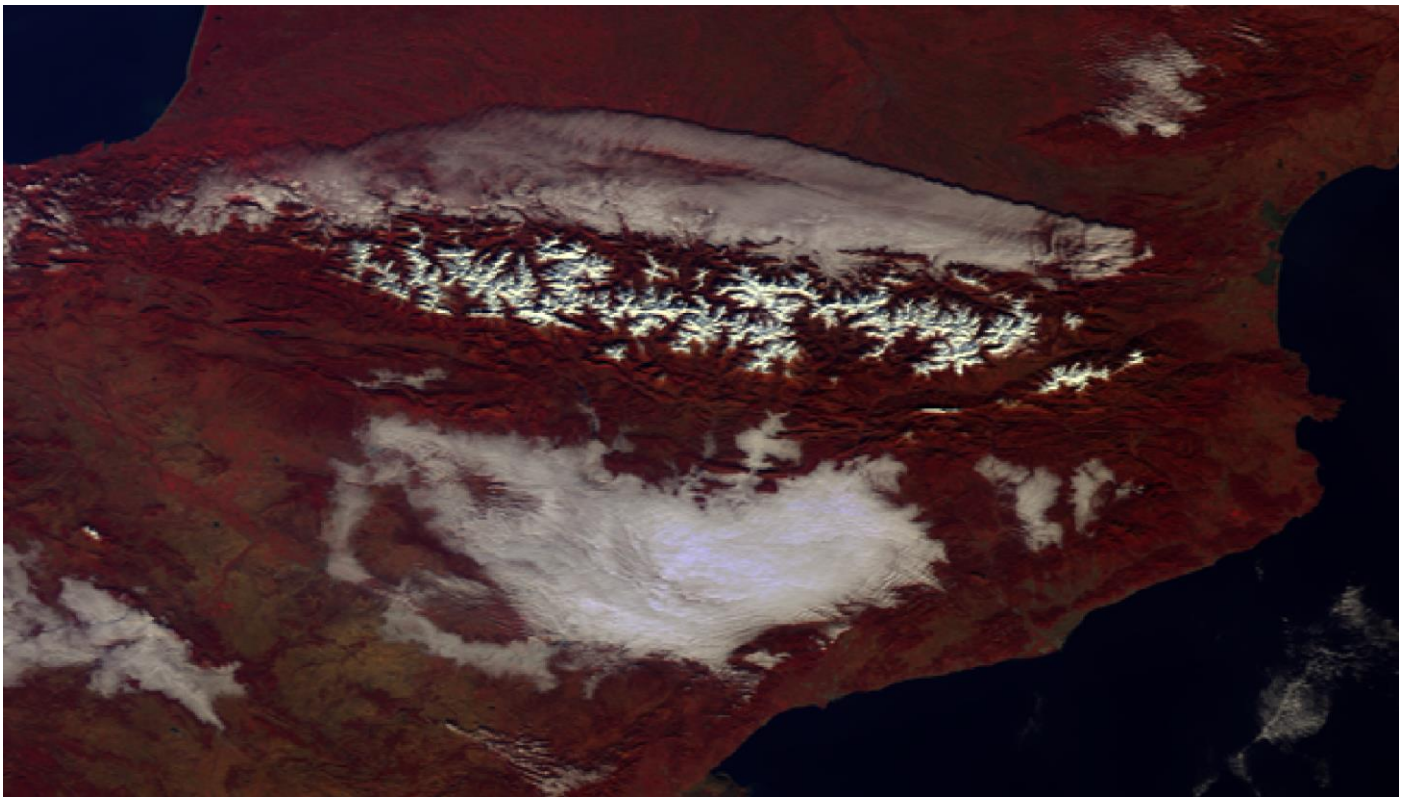


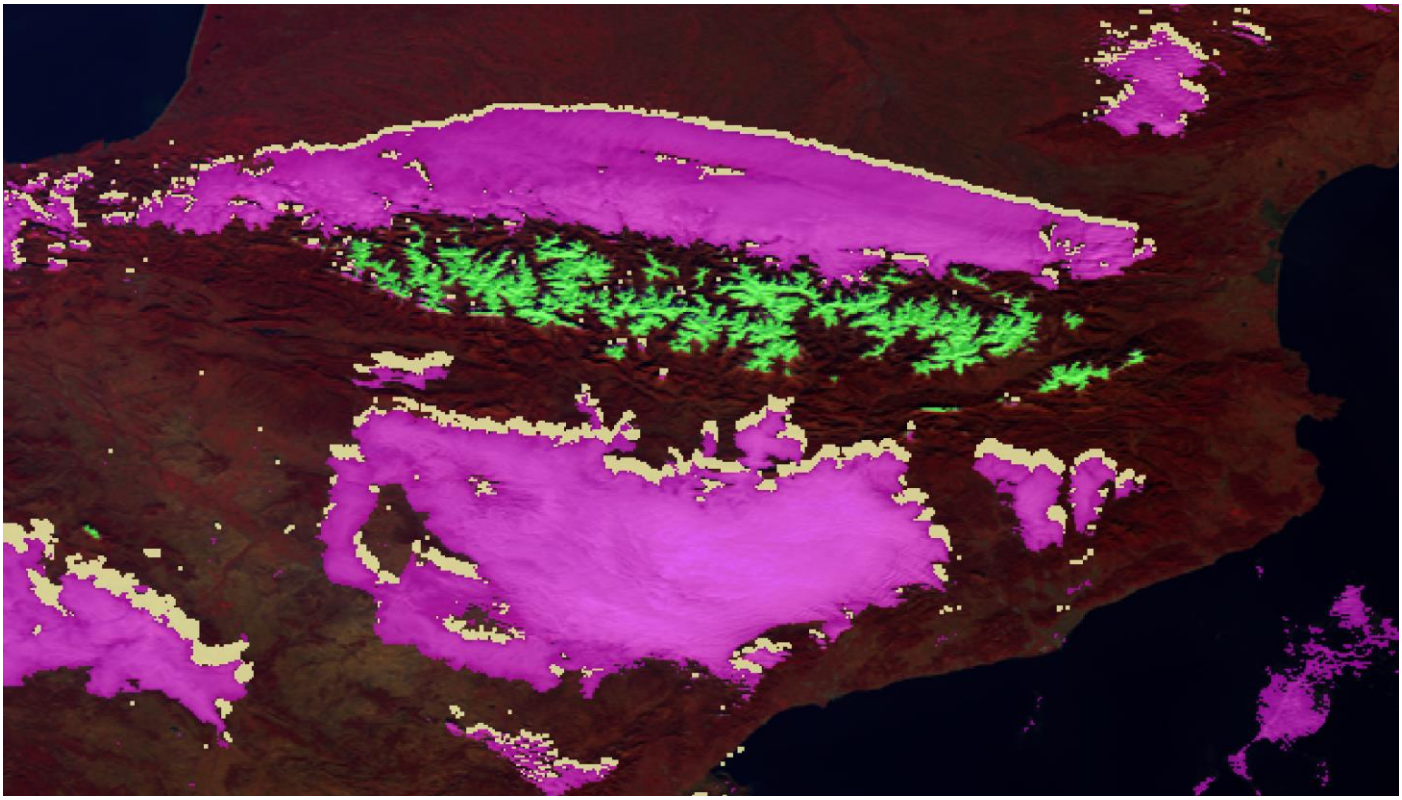


78. PROBAV_L2A_20140621_104105_3_1KM_V103 (Caucasus)

An interesting image. In the north of mountains are clouds, in the south - fog. All is well masked.

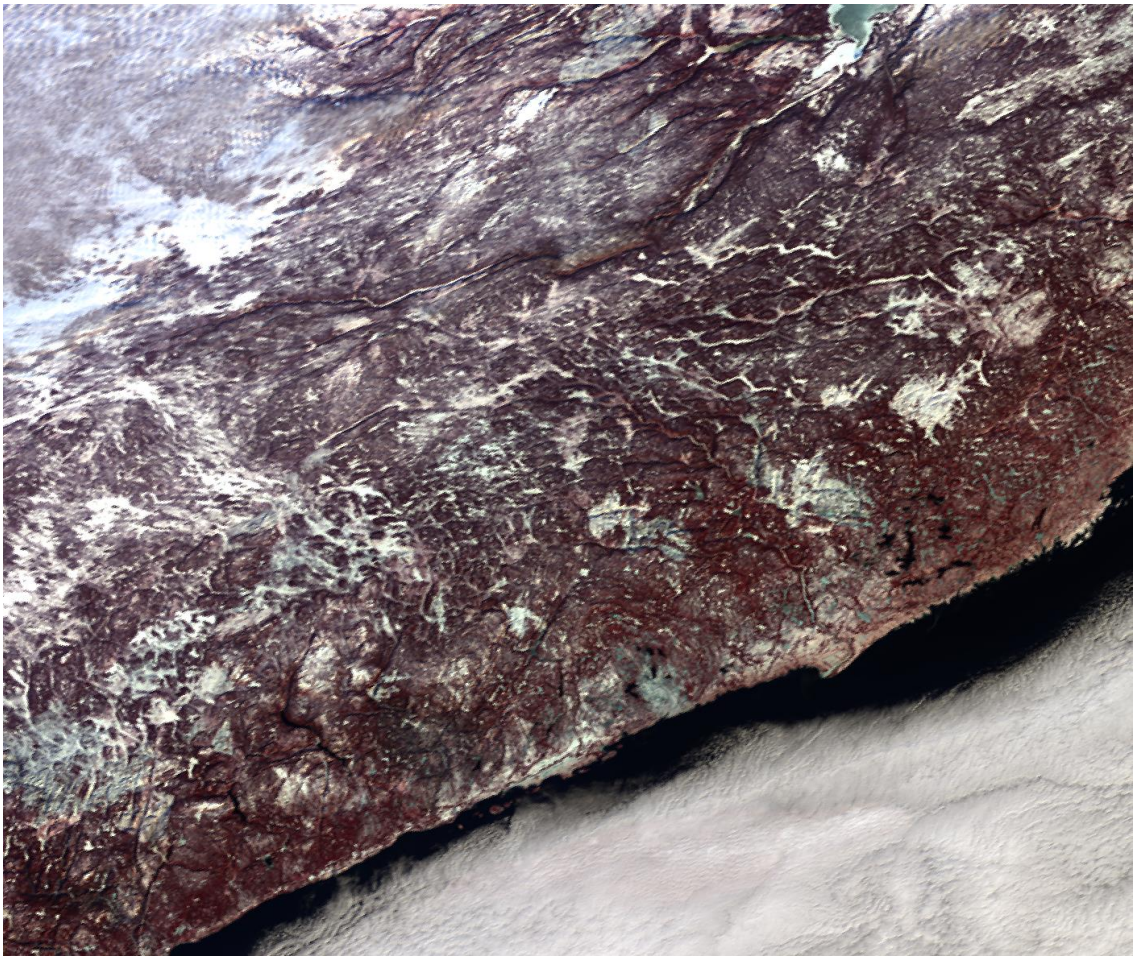
Obviously, the fog was recognized as clouds, the fog has no shadow and there is no such thing in the picture either.

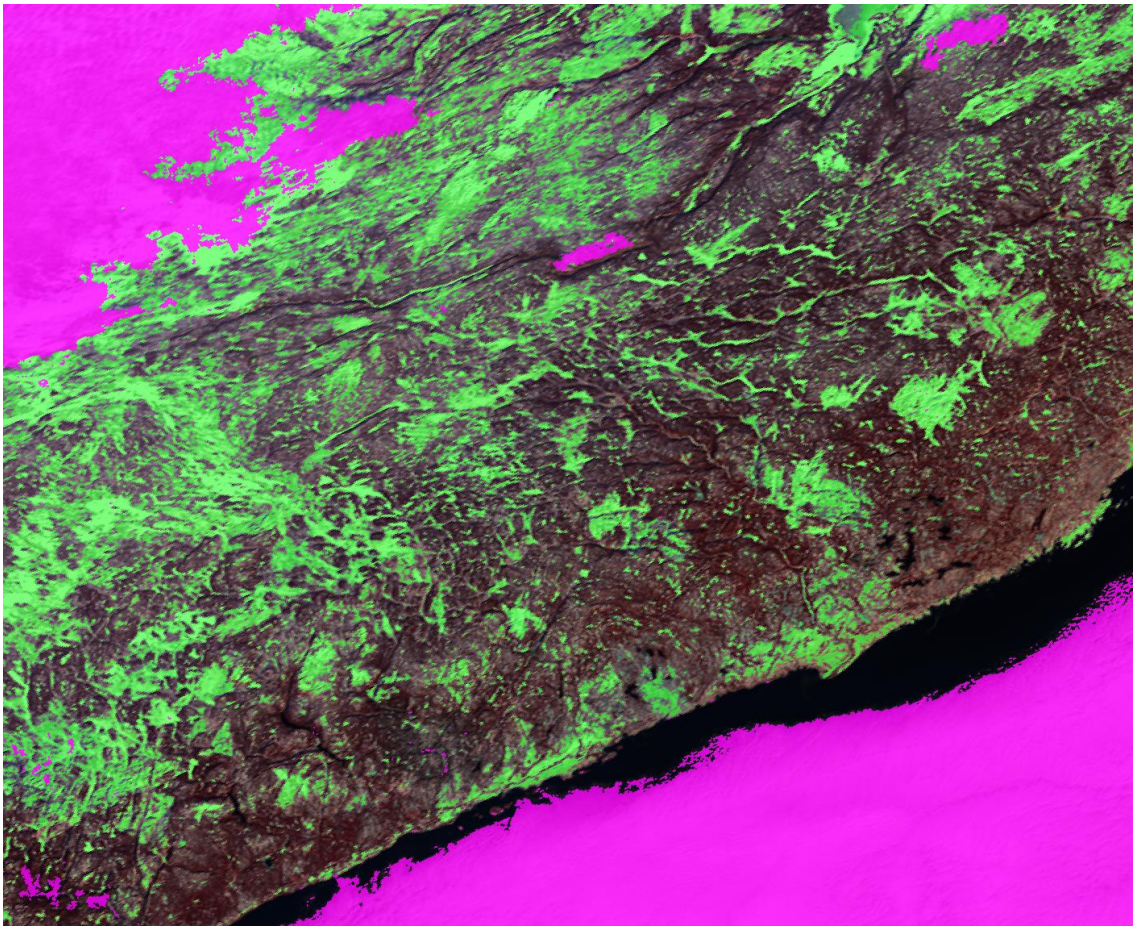




79. PROBAV_L2A_20140621_154448_2_1KM_V103 (new Brunswick)

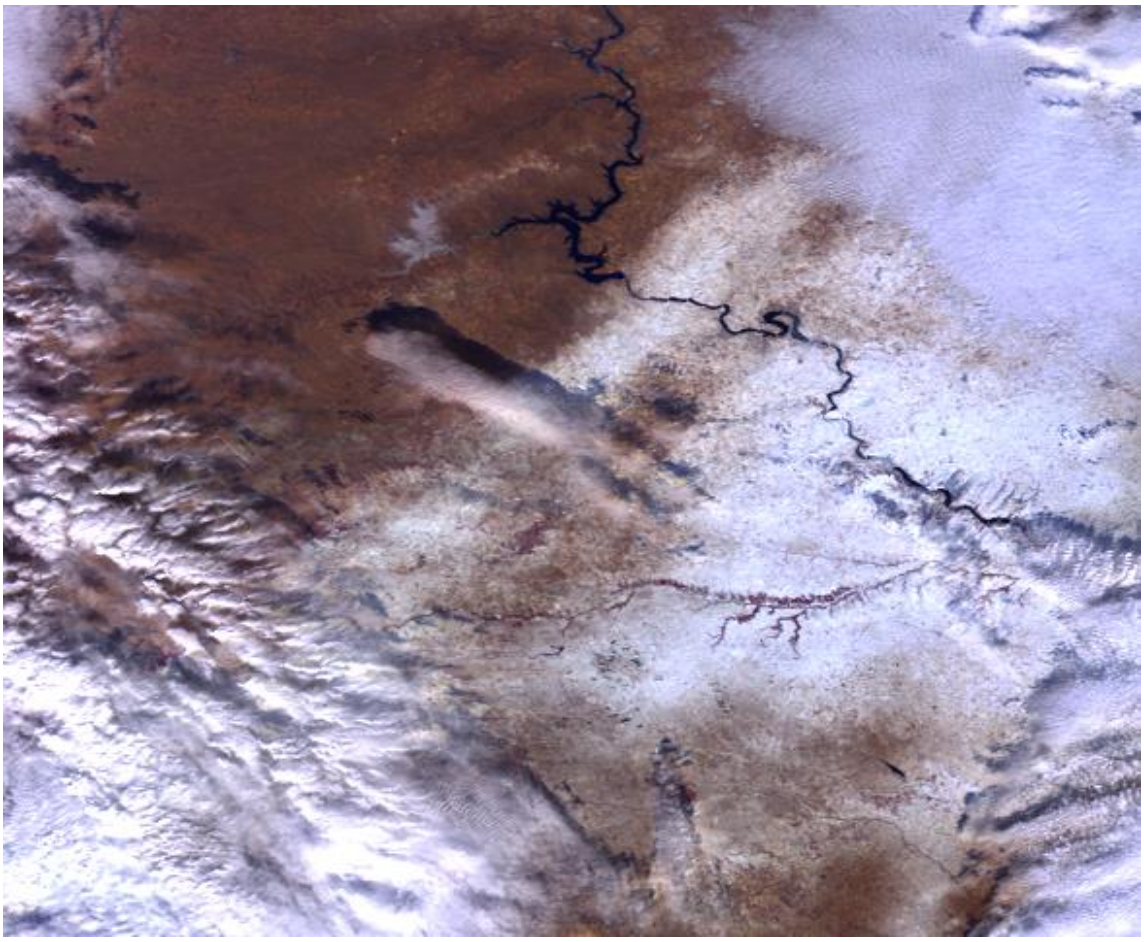
Spatially mixed snow (in this case mostly snow covered coniferous forests) is almost never marked. This is a big flaw.

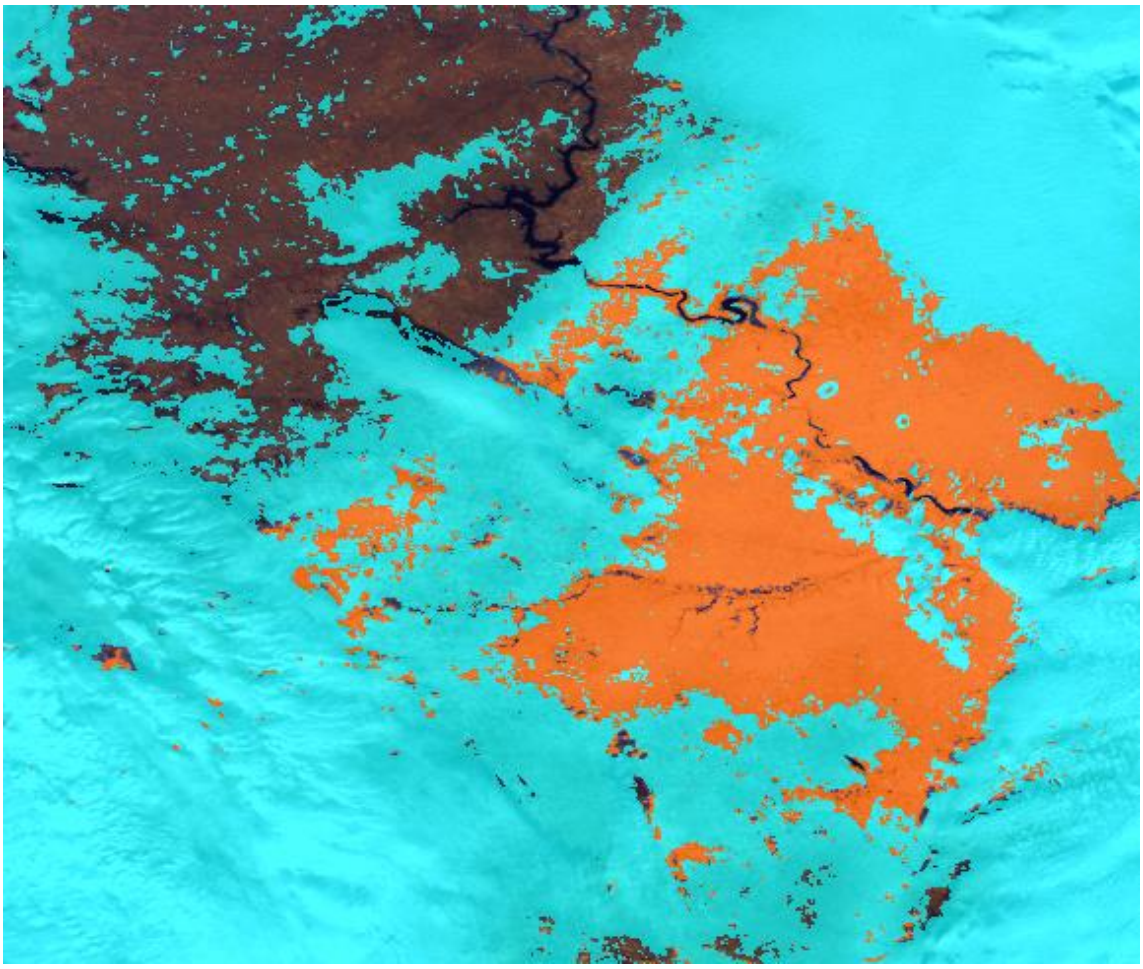




80. PROBAV_L2A_20140621_172608_3_1KM_V103 (Canada)

Here, too, irregularly covered with snow areas (somewhat darker than a closed blanket of snow - the earth peeps out) are incorrectly recognized as a cloud.





81. PROBAV_L2A_20140621_225542_1_1KM_V103

(New Zealand, Tongariro Volcano)
Clouds and snow are well marked.
It is strange that a shadow has been registered around a snow-covered volcano. When analysing the images of this satellite, I never noticed that the dark areas are just automatically recognized like shadows.