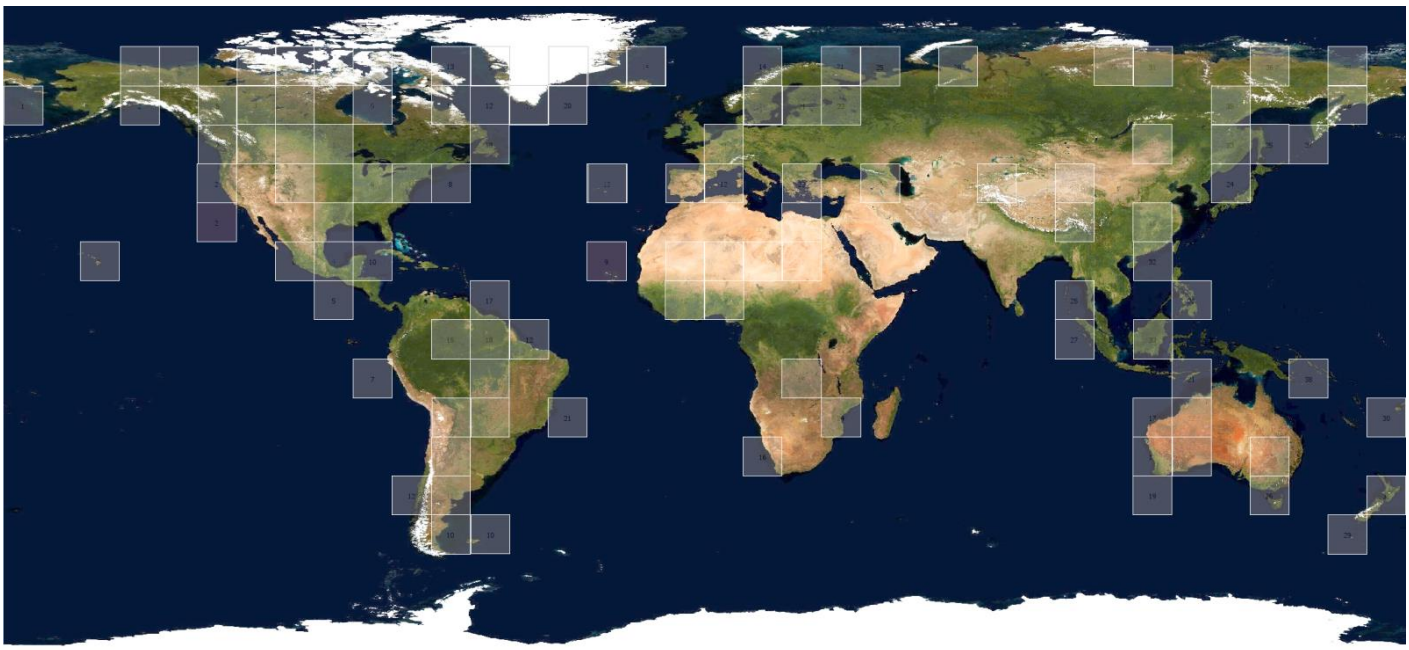
M.Paperin, 28.04.2020

Investigation & Evaluation of "ProbaV-100 m" 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 satellite fragments are examined visually, they are compared with each other, without and with cloud- and ice masks.

120 Satellite fragments (from four seasons) were examined and more than 190 colour RGB images were produced. Each image exists also as individual file.

This is the geographical distribution of examined satellite data.



For the investigation, four 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 not masked pixels, the following mask colours are used

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

The impression that can be obtained after the check of all provided satellite fragments is really positive. I can even announce gingerly that the quality is a little better than I have ever seen. It is strongly dependent on the geographic location, meteorological and astronomical situation, 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. It should be mentioned here that the quality of the masks is independent of the seasons.

As just mentioned, about 15% of all the examined cases indicate some irregularities in the generation of the cloud- or ice masks. In my opinion the method fails to correctly identify the objects here.
The aim of my activity, therefore, is to focus specifically on identifying of method errors and, if possible, systematizing them.

The number of taken pictures makes up a statistically significant sample, therefore (although some meteorological cases were not found among the regarded data) it can be argued that the main errors of the method were detected and presented in this work.

The following irregular cases have been discovered.
They are highlighted:

- Cloud-free pixels are marked as clouds (cloud instead of clear sky).
- Cloudy pixels (except very thin ones) are marked as clear sky (didn't detect a cloud).
- Thin and very thin clouds are **not** marked as clouds.
- A clear sky land/sea snow/ice pixels are marked as cloudy.
- Oversaturated cloud pixels are incorrectly identified as ice.
- The dark, melting clear sky ice pixels are **not** marked as such.
- Spatially-mixed snow covered pixels are **not** recognized as such.
- Sun glint was incorrectly recognized as cloudy.
- Cloud-free salt lake (as well as dry lakes/rivers or sandy) pixels are incorrectly marked as cloudy or icy.
- Shadow mask is shown incorrectly.
- Well done cloud/snow mask.

The masks work satisfactorily in the cases of rather thin (and still recognizable) semi-transparent or some spatially mixed clouds, also for some semi-transparent clouds over ice, less often over desert.

In the case of really very thin but still existing semi-transparent clouds the mask works rather moderately or poorly.

Spatially mixed cumulus clouds are only partially recognized. The edges of small clouds are very transparent (because the size of the small cloud edge is much smaller than the pixel size), so most often they are not recognized as clouds.

The distinction between cloud-free or cloudy snow is difficult due to pre-masking of "bad" pixels for the "blue", "red", "nir", "swir" channels. I call such regions as "saturated areas". The presence of **<! SM_FLAGS.GOOD_BLUE>**-flag changes the quality for both masks, but especially and more often for snow mask.
Most often, very bright and **not** with **<SM_FLAGS.GOOD_BLUE>**-flag pre-masked cloud pixels were wrong indicated as ice.

Dark, slightly melting sea ice is recognized as free water, sometimes as cloudy.

Spatially mixed snow covered as well as deeply snowed but well forested land surfaces (I consider both cases as spatially-mixed snow pixels) are not marked with a snow/ice mask.
In winter in high latitudes, where the conifers grow, the coniferous forests soil is normally covered with deep snow. The dark-green crowns of the trees are usually snow-free or only partially covered with snow. Even deciduous trees without leaves make the snow carpet darker. From a satellite point of view, such winter regions seem a little lighter than in summer (due to snowy soils and some trees) but never quite white (like nearby fields). I call such case as a "veiled snow region" and I identify both kinds of just mentioned pixels belonging to such regions as spatially mixed land-snow covered pixels.

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.

Bright cloud-free beaches and sand spit coastlines are fairly regularly recognized by the method as cloudy.

Sun glint effect interferes with cloud recognition fundamentally, because it itself is very often incorrectly identified as cloudy. This especially affects thin, light and semi-transparent clouds. Usually almost all of these clouds are recognized as such, but it is not clear whether they were recognized: because of the clouds or because of the sun glint.

Cloud-free pixels belonging to the urban areas and artificial structures (mostly shining roofs, glass buildings and structures such as greenhouses etc.) can be confused with clouds by the cloud detection method. The water reservoirs of impressive sizes can be mistaken for clouds.

They can “cast” [inexistent] shadows, which are indicated with the appropriate mask.

The case of fog (marked as a cloud) - was not found in the data sample. Haze was also not found.
Aerosol (mostly sand dust but also smoke) was not found in the present data sample.

The detection of shadows causes a lot of questions. Only a specific part of shadow pixels are marked on the satellite fragment although they are definitely recognizable, also the clouds casting these shadows are recognized and masked. So large parts of the satellite fragment remain without shadow marking. The shadows themselves are sometimes too narrow and their location is shown wrong. This says something about the algorithm with which shadows information was obtained: only the height of the clouds is taken into account, the cloud top height for recognized clouds will be used for the calculation of shadows location, not shadows recognition as such. I could not determine, if the darkening of the surface due to its shading was taken into account. I noticed that the cloud altitude calculation algorithm works here better; better than for ProbaV-1km resolution. However I find the current shadow mask not quite satisfactory.

Used documents

http://proba-v.vgt.vito.be/sites/proba-v.vgt.vito.be/files/products_user_manual.pdf (May 2018)
Investigation & Evaluation of "ProbaV-1km" cloud masking FinalReport.pdf (M.P., January 2020)
Evaluation_of_ProbaV-333m_cloud_mask.pdf (M.P., July 2019)
http://www.brockmann-consult.de/CloudStructures/index.htm (M.P., June 2012)
As in previous works, the concept of subjective numerical rating is introduced here. The Subjective Cloud Mask Quality Rating (**SCMQR**) is displayed from 0 to 10, whereby "0" - the worst and "10" - the best grade is.

As part of the "qualitative" grading, the SCMQR for the functioning of the entire cloud and ice masks is in all cases about 8÷8.5.

The **SCMQR** for different cloud types in the sense of ⭕ (didn't note a cloud):

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

The SCMQR for different surfaces in the sense of ⭕ (didn't note a cloud):

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

The SCMQR for different surfaces in the sense of 🔵 (cloud instead of clear sky):

Media	***Surface***	***SCMQR***
Cloud free over land	over „usual" land	9,5 - 10
	over desert	7,5 - 8,5
	over salt lake	2,0 - 5,0
	over urban area	5,0 - 8,5
	over ice/snow	2,0 - 7,0
	over spatially mixed ice/snow	2,0 - 4,0
Cloud free over water	over water	9,5 - 10
	over Inland water	9,0 - 9,5
	over floating ice	5,0 - 7,5
	over sun glint	2,0 - 5,0

The **SCMQR** for the "Snow/Ice mask quality rating" in the sense of "right masking of really ice":

Media	***Surface***	***SCMQR***
Inland ice/snow (cloud free)	Thick snow layer	9,5 - 10
	Spatially mixed, veiled, or slightly sprinkled	2,0 - 6,0
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, this does not apply to saturated areas, when the really very bright pixels can be seen, where clouds and ice can easily be mix-up.
^ So-called "spatially mixed clouds" - clouds that are smaller than one pixel size (in our case smaller than $100m^2$)

Considered Data

A List of considered Satellite Data

1. PROBAV_S1_TOA_X00Y01_20140321_100M_V101 (*Bering Sea in the South of Chukotka*)
Some of the clear sky rocks that are not covered (or partially covered only) with snow have been incorrectly identified as a cloud covered surface.

2. PROBAV_S1_TOA_X00Y01_20140321_100M_V101 (*Bering Sea in the South of Chukotka*).
Some of the easily recognizable floating sea ice was not recognized as such.

3. PROBAV_S1_TOA_X03Y00_20140321_100M_V101 (Beaufort Sea)
Iced sea is partially covered with clouds. Some of the clouds were not recognized as such.
Some clouds cast pretty thick shadows. In extreme cases, such shadowed surfaces are so dark that they were identified as cloud- and ice free. In this case, this is not correct.

4. PROBAV_S1_TOA_X03Y01_20140321_100M_V101 (Southeast of Alaska, Gulf of Alaska)
A well done cloud mask and snow mask.
Exceptions are some clear sky valleys, which are partly covered with snow. These valleys are incorrectly identified as cloudy.

5. PROBAV_S1_TOA_X03Y01_20140321_100M_V101 (Southeast of Alaska, Gulf of Alaska, zoomed).
Some spatially-mixed snow covered pixels are incorrectly identified as cloudy.

6. PROBAV_S1_TOA_X04Y00_20140321_100M_V101 (Northeast of Alaska)
The cloudless snowy/icy surface has been incorrectly identified as cloudy.

7. PROBAV_S1_TOA_X05Y01_20140321_100M_V101 (West of Canada, Yukon, Mackenzie River)
Fairly well resolved cloud/snow masking. Some areas that are in my opinion partially covered with snow are not recognized as such.
Some clear sky icy lakes were incorrectly displayed as cloudy.

8. PROBAV_S1_TOA_X05Y01_20140321_100M_V101 (West of Canada, Yukon, Mackenzie River, zoomed).
The icy lakes (s. 7) have been incorrectly identified as cloudy areas.

9. PROBAV_S1_TOA_X05Y02_20140321_100M_V101 (Northeast Pacific in the West of Vancouver Island)
Very thin, semi-transparent clouds above the water but also above the land are normally not noticed and are therefore not displayed with a cloud mask.

10. PROBAV_S1_TOA_X06Y00_20140321_100M_V101 (Victoria island, Canada Arctic Archipelago)
Very thick cloud shadow above the clouds has been recognized as a cloud.

11. PROBAV_S1_TOA_X11Y09_20140321_100M_V101 (Salar de Uyuni, Bolivia)
Salt lake lying under the clear sky was incorrectly identified as a cloud covered region. The moist areas that show water not covered with salt are incorrectly identified as ice.

12. PROBAV_S1_TOA_X11Y09_20140321_100M_V101 (Bolivia, in the south of Titicaca)
Some very thin semi-transparent clouds were not identified as such.

13. PROBAV_S1_TOA_X12Y00_20140321_100M_V101 (Davis Strait, West Geenland)
The clear sky floating ice is masked as cloudy. The ice-free water, cracks between ice floes, was masked as ice.

14. PROBAV_S1_TOA_X12Y12_20140321_100M_V101 (South Atlantic in the Northeast of Falkland Islands)
- Some very bright and pre-masked cloud pixels were indicated as ice.

15. PROBAV_S1_TOA_X13Y01_20140321_100M_V101 (South of Greenland)
- A large amount of continental the clear sky ice is incorrectly identified as cloudy.

16. PROBAV_S1_TOA_X13Y07_20140321_100M_V101 (North Brazil in the Southeast of Amazon Delta)
- Well done.

17. PROBAV_S1_TOA_X14Y00_20140321_100M_V101 (Kommuneqarfik Sermersooq)
- The continental clear sky ice was incorrectly identified as cloudy.

18. PROBAV_S1_TOA_X15Y03_20140321_100M_V101 (Atlantic Ocean around Azores)
- Cloud shadow mask was displayed over the thin clouds.

19. PROBAV_S1_TOA_X17Y03_20140321_100M_V101 (Spain)
- An overall good cloud mask.

20. PROBAV_S1_TOA_X17Y03_20140321_100M_V101 (Spain)
- Thin clouds over the water were not well recognized.

21. PROBAV_S1_TOA_X17Y03_20140321_100M_V101 (Spain, zoomed)
- Well done cloud/shadow mask.
- Some very thin semi-transparent clouds were not recognized as such.

22. PROBAV_S1_TOA_X17Y03_20140321_100M_V101 (Spain, zoomed)
- Cloud-free pixels (urban areas) are marked as clouds.
- The shadows without clouds can be even seen.

23. PROBAV_S1_TOA_X17Y03_20140321_100M_V101 (Spain, zoomed)
- The water reservoirs and roofs of greenhouses of impressive sizes are also mistaken for clouds.

24. PROBAV_S1_TOA_X17Y05_20140321_100M_V101 (West Sahara)
- Quite easily recognizable clouds over the desert were not.

25. PROBAV_S1_TOA_X17Y05_20140321_100M_V101 (West Sahara, zoomed)
- Part of fairly thin cumulus clouds over the desert was not recognized.

26. PROBAV_S1_TOA_X20Y01_20140321_100M_V101 (Belorussia)
- Completely wrongly produced cloud shadow mask.

27. PROBAV_S1_TOA_X20Y01_20140321_100M_V101 (Belorussia, zoomed)
- Completely wrongly produced cloud shadow mask.

28. PROBAV_S1_TOA_X20Y03_20140321_100M_V101 (Greece)
- That's rather good masking.
- Some thin, semi-transparent clouds over the sea remained undetected.

29. PROBAV_S1_TOA_X21Y01_20140321_100M_V101 (Northwest of Russia)
- Several partially snow-covered pixels were incorrectly identified as cloudy or not masked at all.

30. PROBAV_S1_TOA_X22Y03_20140321_100M_V101 (Northwest of Iran, Lake Urmia)
- Some cloud-free probably sandy pixels around the lake are incorrectly masked as.

31. PROBAV_S1_TOA_X24Y00_20140321_100M_V101 (Kara Sea)
- The clear sky floating ice is masked as cloudy.

32. PROBAV_S1_TOA_X25Y03_20140321_100M_V101 (Tajikistan, Badahshan Mountains)
A doubtful snow mask.

33. PROBAV_S1_TOA_X27Y03_20140321_100M_V101 (Dabuxun Lake, Northwest of China)
The sand that lies on the shores of the lakes (and is probably humid to varying degrees) is marked with a cloud mask (more rarely with a snow mask).

34. PROBAV_S1_TOA_X27Y03_20140321_100M_V101 (West Taiji Nai'er Lake, zoomed)
Some cloud-free sandy pixels around the lake are incorrectly masked as snow covered the others as cloudy.

35. PROBAV_S1_TOA_X27Y04_20140321_100M_V101 (East Tibet)
Well done.

36. PROBAV_S1_TOA_X29Y00_20140321_100M_V101 (Laptev Sea)
Floating sea ice and some pixels of cloud- and ice free water - all of this was incorrectly marked as cloudy.

37. PROBAV_S1_TOA_X29Y07_20140321_100M_V101 (West Kalimantan)
A well done cloud mask.

38. PROBAV_S1_TOA_X29Y07_20140321_100M_V101 (In the Northeast of Rejang River Estuary, zoomed)
Some very thin, semi-transparent clouds have not been recognized.

40. PROBAV_S1_TOA_X30Y10_20140321_100M_V101 (South of West Australia)
Small semi-transparent Cumulus clouds and their edges have not been masked as clouds.

41. PROBAV_S1_TOA_X31Y01_20140321_100M_V101 (Yakutia, Amga River, Russia)
The some snow-covered but densely grown with conifers were incorrectly masked as cloudy.
Also the river covered with ice was shown as cloudy.

42. PROBAV_S1_TOA_X33Y02_20140321_100M_V101 (Sea of Okhotsk close to the Southwest of Kamchatka)
The sea floating ice was only partially recognized as such.

43. PROBAV_S1_TOA_X34Y00_20140321_100M_V101 (East Siberian Sea)
The cloud mask is almost completely wrong over this region (the continental ice was masked as cloudy).

44. PROBAV_S1_TOA_X02Y05_20140621_100M_V101 (Hawaii)
Many sun glint pixels were not recognize as such rather as clouds (black cloud mask).
Shadows were not shown everywhere.

45. PROBAV_S1_TOA_X05Y03_20140621_100M_V101 (Pacific Ocean in the West of North California)
Sandy coast was incorrectly identified as cloudy.

46. PROBAV_S1_TOA_X05Y03_20140621_100M_V101 (North California)
The region consists of land, snow and no shadows and is completely covered with semi-transparent clouds..

47. PROBAV_S1_TOA_X07Y00_20140621_100M_V101 (Dease Strait, Queen Maud Gulf, Melbourne Island, Canada)
Relative dark ice was not masked.
Areas partially covered with snow (probably forest) are mostly incorrectly identified as cloudy.

48. PROBAV_S1_TOA_X09Y00_20140621_100M_V101 (North of Baffin Island, Eclipse Sound, Bylot Island)
The cloud-free valleys, probably overgrown with forest, presumably with snow covered soil to varying degrees, were mostly thought (and masked) to be cloudy.

49. PROBAV_S1_TOA_X09Y01_20140621_100M_V101 (Hudson Bay)
Not all floating sea ice has been recognized.

50. PROBAV_S1_TOA_X10Y03_20140621_100M_V101 (Long Beach and other Islands, Long Island, USA)
Sandy coast was incorrectly identified as cloudy.

51. PROBAV_S1_TOA_X10Y03_20140621_100M_V101 (Atlantic Ocean in the East of Long Island, USA)
Clear sky sun glint area was incorrectly identified as cloudy.

52. PROBAV_S1_TOA_X11Y01_20140621_100M_V101 (Labrador Peninsula)
Cloud free areas “partially” covered with snow (probably forests) are mostly incorrectly identified as cloudy.

53. PROBAV_S1_TOA_X11Y01_20140621_100M_V101 (Labrador Sea, Hudson Strait)
Many pixels of drifting brash ice have not been recognized.

54. PROBAV_S1_TOA_X11Y10_20140621_100M_V101 (Ands, Region de Antofagasta, Chile)
Salt lakes and dry areas were recognized as cloudy.

55. PROBAV_S1_TOA_X27Y03_20140621_100M_V101 (Chakayan Lake, Province Qinghai, Central China)
Salt or/and dry lake pixels were recognized as cloudy or icy.

56. PROBAV_S1_TOA_X27Y07_20140621_100M_V101 (Indian Ocean in the West of Sumatra)
The semi-transparent clouds were not masked.

57. PROBAV_S1_TOA_X06Y02_20140921_100M_V101 (Columbia Mountains, West Canada)
Several clearly recognizable snow pixels were not marked as such.

58. PROBAV_S1_TOA_X08Y05_20140921_100M_V101 (Panama)
The cloud shadows are too short.

59. PROBAV_S1_TOA_X08Y05_20140921_100M_V101 (Pacific in the south of Panama)
A numerous of sun glint pixels were incorrectly identified as cloudy.

60. PROBAV_S1_TOA_X12Y01_20141221_100M_V101 (Davis Strait in the west of Greenland)
Semi-transparent clouds are hardly visible, however, if contrasted, many clouds can be recognized there.

61. PROBAV_S1_TOA_X12Y06_20140621_100M_V101 (Atlantic Ocean in the North of Suriname)
Some cloud pixels were masked as snow.
Some shadows are wrong, from another ones are missing any trace.

62. PROBAV_S1_TOA_X15Y03_20140621_100M_V101 (Azores, Atlantic Ocean)
Sun glint pixels were wrong masked as cloudy (and even ice!).

63. PROBAV_S1_TOA_X17Y06_20140921_100M_V101 (West Africa, Côte d'Ivoire)
Not all clouds were found.

64. PROBAV_S1_TOA_X18Y02_20140921_100M_V101 (France)
The length of the shadow was not determined correctly.

65. PROBAV_S1_TOA_X18Y05_20140921_100M_V101 (Sahara, Mali)
Semi-transparent Cumulus clouds could not been recognized.

66. PROBAV_S1_TOA_X20Y04_20140921_100M_V101 (Egypt)
Some dry lake pixels (probably salt lake) were incorrectly determined to be cloudy.

67. PROBAV_S1_TOA_X08Y04_20141221_100M_V101 (Texas)
Incorrect determined of shadows location.

68. PROBAV_S1_TOA_X11Y12_20141221_100M_V101 (South Atlantic in the East of Patagonia)
A lot of semi-transparent cloud pixels were not identified as "cloudy".

69. PROBAV_S1_TOA_X12Y02_20141221_100M_V101 (Newfoundland)
Some spatially-mixed snow covered pixels are incorrectly identified as cloudy.

70. PROBAV_S1_TOA_X29Y02_20141221_100M_V101 (Lake Zun-Torey, Dahuria)
Some spatially-mixed snow covered pixels are incorrectly identified as cloudy.

71. PROBAV_S1_TOA_X30Y08_20141221_100M_V101 (Sawu Sea, Banda Sea, Timor)
A lot of sun glint pixels were misidentified here: some as clouds, others as ice.

72. PROBAV_S1_TOA_X30Y09_20141221_100M_V101 (Eighty Mile Beach, Northwest Australia)
The wrong masking of sun glint pixels.

73. PROBAV_S1_TOA_X32Y10_20141221_100M_V101 (South Australia)
A dry (or salt) lake is incorrect masked as ice.

74. PROBAV_S1_TOA_X32Y11_20141221_100M_V101 (Lake Tyrrell, Australia)
The dry (salt?) clear sky lake is wrong masked as cloudy/icy

75. PROBAV_S1_TOA_X35Y09_20141221_100M_V101 (Great Sea Reef, Kia Island, Fiji)
The chain of sand banks or coral islets covered with the bright water (as well as sun glint area on the right) is wrong recognized as cloudy.

76. PROBAV_S1_TOA_X35Y11_20141221_100M_V101 (New Zealand Alps)
Some areas that are only partially [spatially] covered with snow are masked as “cloudy”.

77. PROBAV_S1_TOA_X12Y08_20140921_100M_V101 (Central Brazil)
Spatially mixed cumulus clouds over the land are only partially recognized.

78. PROBAV_S1_TOA_X08Y04_20140921_100M_V101 (Gulf of Mexico)
Spatially mixed cumulus clouds over the land are only partially recognized.

79. PROBAV_S1_TOA_X19Y10_20140921_100M_V101 (South Atlantic in the southwest of Namib)
Short chains of small cumulus clouds (cloud streets) were mostly not recognized as clouds.

80. PROBAV_S1_TOA_X15Y03_20140621_100M_V101 (Atlantic Ocean in the East of Azores)
The wrong masking of sun glint pixels.

A List of considered Satellite Data sorted by cases of irregularity

- **Cloud-free pixels are marked as clouds (cloud instead of clear sky)**

22. PROBAV_S1_TOA_X17Y03_20140321_100M_V101 (Spain, zoomed)
- Cloud-free pixels (urban areas) are marked as clouds.

23. PROBAV_S1_TOA_X17Y03_20140321_100M_V101 (Spain, zoomed)
- The water reservoirs and roofs of greenhouses of impressive sizes are also mistaken for clouds.

36. PROBAV_S1_TOA_X29Y00_20140321_100M_V101 (Laptev Sea)
- Floating sea ice and some pixels of cloud- and ice free water - all of this was incorrectly marked as cloudy.

- **Cloudy pixels (except very thin ones) are marked as clear sky (didn't note a cloud)**

24. PROBAV_S1_TOA_X17Y05_20140321_100M_V101 (West Sahara)
- Quite easily recognizable clouds over the desert were not.

46. PROBAV_S1_TOA_X05Y03_20140621_100M_V101 (North California)
- The region consists of land, snow and no shadows and is completely covered with semi-transparent clouds.

63. PROBAV_S1_TOA_X17Y06_20140921_100M_V101 (West Africa, Côte d'Ivoire)
- Not all clouds were found.

- **Thin and very thin clouds are not marked as clouds**

3. PROBAV_S1_TOA_X03Y00_20140321_100M_V101 (Beaufort Sea)
- Iced sea is partially covered with clouds. Some of the clouds were not recognized as such.

9. PROBAV_S1_TOA_X05Y02_20140321_100M_V101 (Northeast Pacific in the West of Vancouver Island)
- Very thin, semi-transparent clouds above the water but also above the land, were not masked.

12. PROBAV_S1_TOA_X11Y09_20140321_100M_V101 (Bolivia, in the south of Titicaca)
- Some very thin semi-transparent clouds were not identified as such.

20. PROBAV_S1_TOA_X17Y03_20140321_100M_V101 (Spain)
- Thin clouds over the water were not well recognized.

21. PROBAV_S1_TOA_X17Y03_20140321_100M_V101 (Spain, zoomed)
- Some very thin semi-transparent clouds were not recognized as such.

25. PROBAV_S1_TOA_X17Y05_20140321_100M_V101 (West Sahara, zoomed)
- Part of fairly thin cumulus clouds over the desert was not recognized.

28. PROBAV_S1_TOA_X20Y03_20140321_100M_V101 (Greece)
- Some thin, semi-transparent clouds over the sea remained undetected.

38. PROBAV_S1_TOA_X29Y07_20140321_100M_V101 (In the Northeast of Rejang River Estuary, zoomed)
- Some very thin, semi-transparent clouds have not been recognized.

40. PROBAV_S1_TOA_X30Y10_20140321_100M_V101 (South of West Australia)
- Small semi-transparent Cumulus clouds and their edges have not been masked as clouds.

56. PROBAV_S1_TOA_X27Y07_20140621_100M_V101 (Indian Ocean in the West of Sumatra)
- The semi-transparent clouds were not masked.

60. PROBAV_S1_TOA_X12Y01_20141221_100M_V101 (Davis Strait in the west of Greenland)

- The entire cloud- and ice mask looks too chaotic and not always correct.

65. PROBAV_S1_TOA_X18Y05_20140921_100M_V101 (Sahara, Mali)
- Semi-transparent Cumulus clouds could not been recognized.

68. PROBAV_S1_TOA_X11Y12_20141221_100M_V101 (South Atlantic in the East of Patagonia)
- A lot of semi-transparent cloud pixels were not identified as "cloudy".

77. PROBAV_S1_TOA_X12Y08_20140921_100M_V101 (Central Brazil)
- Spatially mixed cumulus clouds over the land are only partially recognized.

78. PROBAV_S1_TOA_X08Y04_20140921_100M_V101 (Gulf of Mexico)
- Spatially mixed cumulus clouds over the land are only partially recognized.

79. PROBAV_S1_TOA_X19Y10_20140921_100M_V101 (South Atlantic in the southwest of Namib)
- Short chains of small cumulus clouds (cloud streets) were mostly not recognized as clouds.

- A clear sky land/sea snow/ice pixels are marked as cloudy

1. PROBAV_S1_TOA_X00Y01_20140321_100M_V101 (*Bering Sea in the South of Chukotka*)
- Some of the clear sky rocks that are not covered with snow have been incorrectly identified as a cloud covered surface.

4. PROBAV_S1_TOA_X03Y01_20140321_100M_V101 (Southeast of Alaska, Gulf of Alaska)
- The partly snow-covered valleys are incorrectly identified as cloudy.

7. PROBAV_S1_TOA_X05Y01_20140321_100M_V101 (West of Canada, Yukon, Mackenzie River)
- Some clear sky icy lakes were incorrectly displayed as cloudy.

8. PROBAV_S1_TOA_X05Y01_20140321_100M_V101 (West of Canada, Yukon, Mackenzie River, zoomed).
- The icy lakes (s. 7) have been incorrectly identified as cloudy areas.

13. PROBAV_S1_TOA_X12Y00_20140321_100M_V101 (Davis Strait, West Geenland)
- The clear sky floating ice is masked as cloudy. The ice (and cloud) free water, cracks between ice floes, was masked as ice.

15. PROBAV_S1_TOA_X13Y01_20140321_100M_V101 (South of Greenland)
- A large amount of continental the clear sky ice is incorrectly identified as cloudy.

17. PROBAV_S1_TOA_X14Y00_20140321_100M_V101 (Kommuneqarfik Sermersooq)
- The continental clear sky ice was incorrectly identified as cloudy.

31. PROBAV_S1_TOA_X24Y00_20140321_100M_V101 (Kara Sea)
- The clear sky floating ice is masked as cloudy.

36. PROBAV_S1_TOA_X29Y00_20140321_100M_V101 (Laptev Sea)
- Floating sea ice and some pixels of cloud- and ice free water - all of this was incorrectly marked as cloudy.

41. PROBAV_S1_TOA_X31Y01_20140321_100M_V101 (Yakutia, Amga River, Russia)
- Also the river covered with ice was shown as cloudy.

43. PROBAV_S1_TOA_X34Y00_20140321_100M_V101 (East Siberian Sea)
- The cloud mask is almost completely wrong over this region (the continental ice was masked as cloudy).

- Oversaturated cloud pixels are incorrectly identified as ice

14. PROBAV_S1_TOA_X12Y12_20140321_100M_V101 (South Atlantic in the Northeast of Falkland Islands)
- Some very bright and pre-masked cloud pixels were indicated as ice.

61. PROBAV_S1_TOA_X12Y06_20140621_100M_V101 (Atlantic Ocean in the North of Suriname)
- Some cloud pixels were masked as snow.

- The dark, melting clear sky ice pixels are not marked as such

2. PROBAV_S1_TOA_X00Y01_20140321_100M_V101 (*Bering Sea in the South of Chukotka*).
- Some of the easily recognizable floating sea ice was not recognized as such.

36. PROBAV_S1_TOA_X29Y00_20140321_100M_V101 (Laptev Sea)
- Floating sea ice and some pixels of cloud- and ice free water - all of this was incorrectly marked as cloudy.

42. PROBAV_S1_TOA_X33Y02_20140321_100M_V101 (Sea of Okhotsk close to the Southwest of Kamchatka)
- The sea floating ice was only partially recognized as such.

49. PROBAV_S1_TOA_X09Y01_20140621_100M_V101 (Hudson Bay)
- Not all floating sea ice has been recognized.

47. PROBAV_S1_TOA_X07Y00_20140621_100M_V101 (Dease Strait, Queen Maud Gulf, Melbourne Island, Canada)
- Relative dark ice was not masked.
- Areas partially covered with snow (probably forest) are mostly incorrectly identified as cloudy.

53. PROBAV_S1_TOA_X11Y01_20140621_100M_V101 (Labrador Sea, Hudson Strait)
- Many pixels of drifting brash ice have not been recognized.

- **<u>Spatially-mixed snow covered pixels are not recognized as such</u>**

1. PROBAV_S1_TOA_X00Y01_20140321_100M_V101 (*Bering Sea in the South of Chukotka*)
- Some of the clear sky rocks that are not covered with snow have been incorrectly identified as a cloud covered surface.

5. PROBAV_S1_TOA_X03Y01_20140321_100M_V101 (Southeast of Alaska, Gulf of Alaska, zoomed).
- Some spatially-mixed snow covered pixels are incorrectly identified as cloudy.

6. PROBAV_S1_TOA_X04Y00_20140321_100M_V101 (Northeast of Alaska)
- The cloudless snowy/icy surface has been incorrectly identified as cloudy.

7. PROBAV_S1_TOA_X05Y01_20140321_100M_V101 (West of Canada, Yukon, Mackenzie River)
- Some areas that are in my opinion partially covered with snow are not recognized as such.

29. PROBAV_S1_TOA_X21Y01_20140321_100M_V101 (Northwest of Russia)
- Partially snow-covered pixels were incorrectly identified as cloudy or not masked at all.

32. PROBAV_S1_TOA_X25Y03_20140321_100M_V101 (Tajikistan, Badahshan Mountains)
A doubtful snow mask.

41. PROBAV_S1_TOA_X31Y01_20140321_100M_V101 (Yakutia, Amga River, Russia)
- The some snow-covered but densely grown with conifers were incorrectly masked as cloudy.

48. PROBAV_S1_TOA_X09Y00_20140621_100M_V101 (North of Baffin Island, Eclipse Sound, Bylot Island)
- The cloud-free valleys, overgrown with forest, with snow covered soil, were mostly masked to be cloudy.

52. PROBAV_S1_TOA_X11Y01_20140621_100M_V101 (Labrador Peninsula)
- Cloud free areas “partially” covered with snow (probably forests) are mostly incorrectly identified as cloudy.

57. PROBAV_S1_TOA_X06Y02_20140921_100M_V101 (Columbia Mountains, West Canada)
- Several clearly recognizable snow pixels were not marked as such.

69. PROBAV_S1_TOA_X12Y02_20141221_100M_V101 (Newfoundland)
- Some spatially-mixed snow covered pixels are incorrectly identified as cloudy.

70. PROBAV_S1_TOA_X29Y02_20141221_100M_V101 (Lake Zun-Torey, Dahuria)
- Some spatially-mixed snow covered pixels are incorrectly identified as cloudy.

76. PROBAV_S1_TOA_X35Y11_20141221_100M_V101 (New Zealand Alps)
- Some areas that are only partially [spatially] covered with snow are masked as “cloudy”.

- **<u>Sun glint was incorrectly recognized as cloudy</u>**

44. PROBAV_S1_TOA_X02Y05_20140621_100M_V101 (Hawaii)
- Many sun glint pixels were not recognized as such rather as clouds.

51. PROBAV_S1_TOA_X10Y03_20140621_100M_V101 (Atlantic Ocean in the East of Long Island, USA)
- Clear sky sun glint area was incorrectly identified as cloudy.

59. PROBAV_S1_TOA_X08Y05_20140921_100M_V101 (Pacific in the south of Panama)

- A numerous of sun glint pixels were incorrectly identified as cloudy.

62. PROBAV_S1_TOA_X15Y03_20140621_100M_V101 (Azores, Atlantic Ocean)
- Sun glint pixels were wrong masked as cloudy (and even ice!).

71. PROBAV_S1_TOA_X30Y08_20141221_100M_V101 (Sawu Sea, Banda Sea, Timor)
- A lot of sun glint pixels were misidentified here: some as clouds, others as ice.

72. PROBAV_S1_TOA_X30Y09_20141221_100M_V101 (Eighty Mile Beach, Northwest Australia)
- The wrong masking of sun glint pixels.

75. PROBAV_S1_TOA_X35Y09_20141221_100M_V101 (Great Sea Reef, Kia Island, Fiji)
- The chain of sand banks or coral islets covered with the bright water (as well as sun glint area on the right) is wrong recognized as cloudy.

80. PROBAV_S1_TOA_X15Y03_20140621_100M_V101 (Atlantic Ocean in the East of Azores)
- The wrong masking of sun glint pixels.

- Salt (dry) lakes pixels or sandy pixels are incorrectly marked as cloudy or icy

11. PROBAV_S1_TOA_X11Y09_20140321_100M_V101 (Salar de Uyuni, Bolivia)
- Salt lake pixels were incorrectly identified as a cloud covered. The moist areas that show not covered with salt water are incorrectly identified as ice.

30. PROBAV_S1_TOA_X22Y03_20140321_100M_V101 (Northwest of Iran, Lake Urmia)
- Some cloud-free sandy pixels around the lake are incorrectly masked as cloudy (wet sand masked as ice).

33. PROBAV_S1_TOA_X27Y03_20140321_100M_V101 (Dabuxun Lake, Northwest of China)
- The sand that lies on the shores of the lakes (and is probably humid to varying degrees) is marked with a cloud mask (more rarely with a snow mask).

34. PROBAV_S1_TOA_X27Y03_20140321_100M_V101 (West Taiji Nai'er Lake, zoomed)
- Some cloud-free sandy pixels around the lake are incorrectly masked as snow covered the others as cloudy.

45. PROBAV_S1_TOA_X05Y03_20140621_100M_V101 (Pacific Ocean in the West of North California)
- Sandy coast was incorrectly identified as cloudy.

50. PROBAV_S1_TOA_X10Y03_20140621_100M_V101 (Long Beach and other Islands, Long Island, USA)
- Sandy coast was incorrectly identified as cloudy.

54. PROBAV_S1_TOA_X11Y10_20140621_100M_V101 (Ands, Region de Antofagasta, Chile)
- Salt lakes and dry areas were recognized as cloudy.

55. PROBAV_S1_TOA_X27Y03_20140621_100M_V101 (Chakayan Lake, Province Qinghai, Central China)
- Salt or/and dry lake pixels were recognized as cloudy or icy.

66. PROBAV_S1_TOA_X20Y04_20140921_100M_V101 (Egypt)
- Some dry lake pixels (probably salt lake) were incorrectly determined to be cloudy.

73. PROBAV_S1_TOA_X32Y10_20141221_100M_V101 (South Australia)
- A dry (or salt) lake is incorrect masked as ice.

74. PROBAV_S1_TOA_X32Y11_20141221_100M_V101 (Lake Tyrrell, Australia)
- The dry (salt?) clear sky lake is wrong masked as cloudy/icy

- Shadow mask is shown incorrectly

3. PROBAV_S1_TOA_X03Y00_20140321_100M_V101 (Beaufort Sea)
- Not correct masked shadows.

10. PROBAV_S1_TOA_X06Y00_20140321_100M_V101 (Victoria island, Canada Arctic Archipelago)
- Very thick cloud shadow above the clouds has been recognized as a cloud.

18. PROBAV_S1_TOA_X15Y03_20140321_100M_V101 (Atlantic Ocean around Azores)

- Cloud shadow mask was displayed over the thin clouds.

22. PROBAV_S1_TOA_X17Y03_20140321_100M_V101 (Spain, zoomed)
- The shadows without clouds can be even seen.

26. PROBAV_S1_TOA_X20Y01_20140321_100M_V101 (Belorussia)
- Completely wrongly produced cloud shadow mask.

27. PROBAV_S1_TOA_X20Y01_20140321_100M_V101 (Belorussia, zoomed)
- Completely wrongly produced cloud shadow mask.

44. PROBAV_S1_TOA_X02Y05_20140621_100M_V101 (Hawaii)
- Shadows were not shown everywhere.

58. PROBAV_S1_TOA_X08Y05_20140921_100M_V101 (Panama)
- The cloud shadows are too short.

64. PROBAV_S1_TOA_X18Y02_20140921_100M_V101 (France)
- The length of the shadow was not determined correctly.

67. PROBAV_S1_TOA_X08Y04_20141221_100M_V101 (Texas)
- Incorrect determined of shadows location.

61. PROBAV_S1_TOA_X12Y06_20140621_100M_V101 (Atlantic Ocean in the North of Suriname)
- Some shadows are wrong, from another ones are missing any trace.

- **<u>Well done cloud/snow mask</u>**

4. PROBAV_S1_TOA_X03Y01_20140321_100M_V101 (Southeast of Alaska, Gulf of Alaska)
- A well done cloud mask and snow mask.

16. PROBAV_S1_TOA_X13Y07_20140321_100M_V101 (North Brazil in the Southeast of Amazon Delta)
- Well done.

19. PROBAV_S1_TOA_X17Y03_20140321_100M_V101 (Spain)
- An overall good cloud mask.

21. PROBAV_S1_TOA_X17Y03_20140321_100M_V101 (Spain, zoomed)
- Well done cloud/shadow mask.

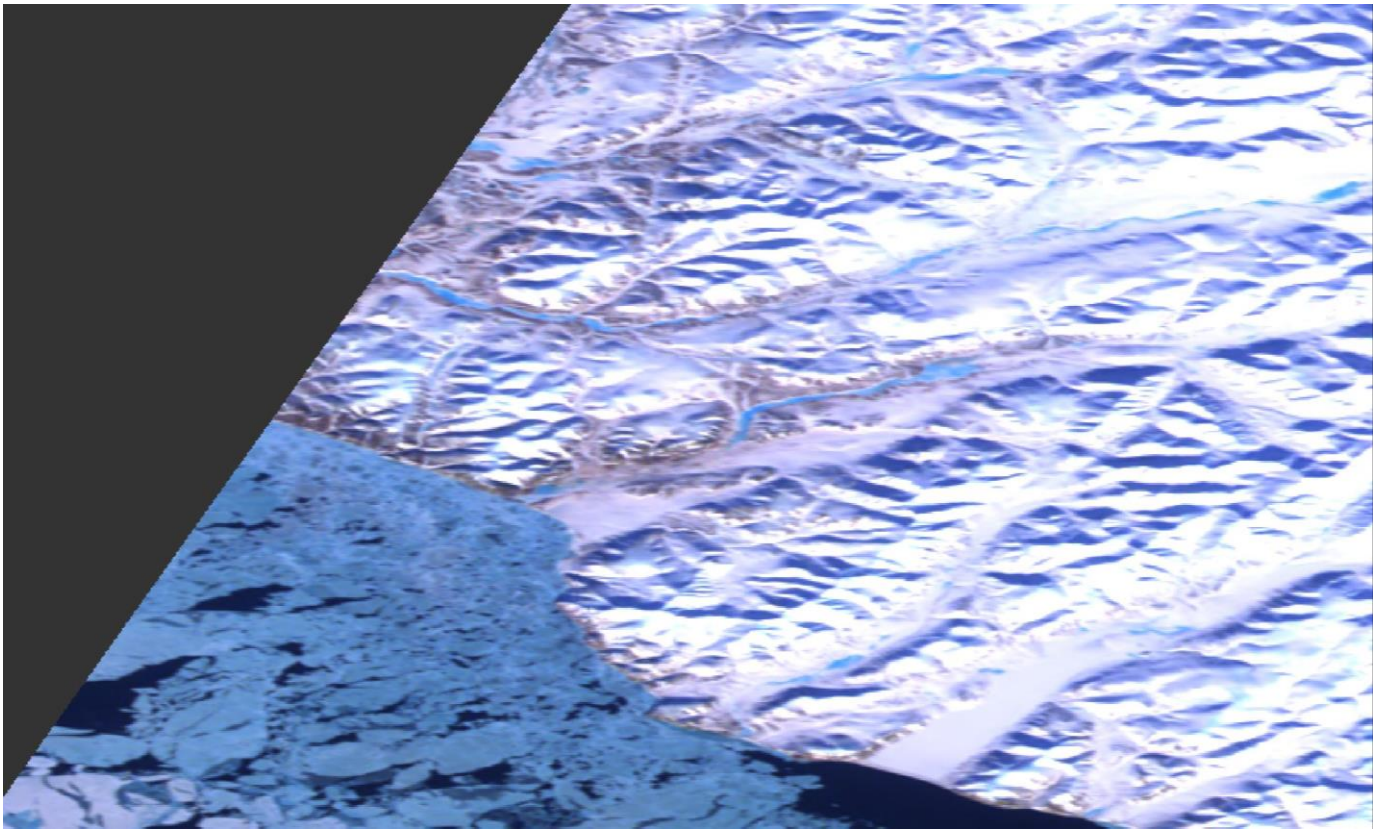
37. PROBAV_S1_TOA_X29Y07_20140321_100M_V101 (West Kalimantan)
- A well done cloud mask.

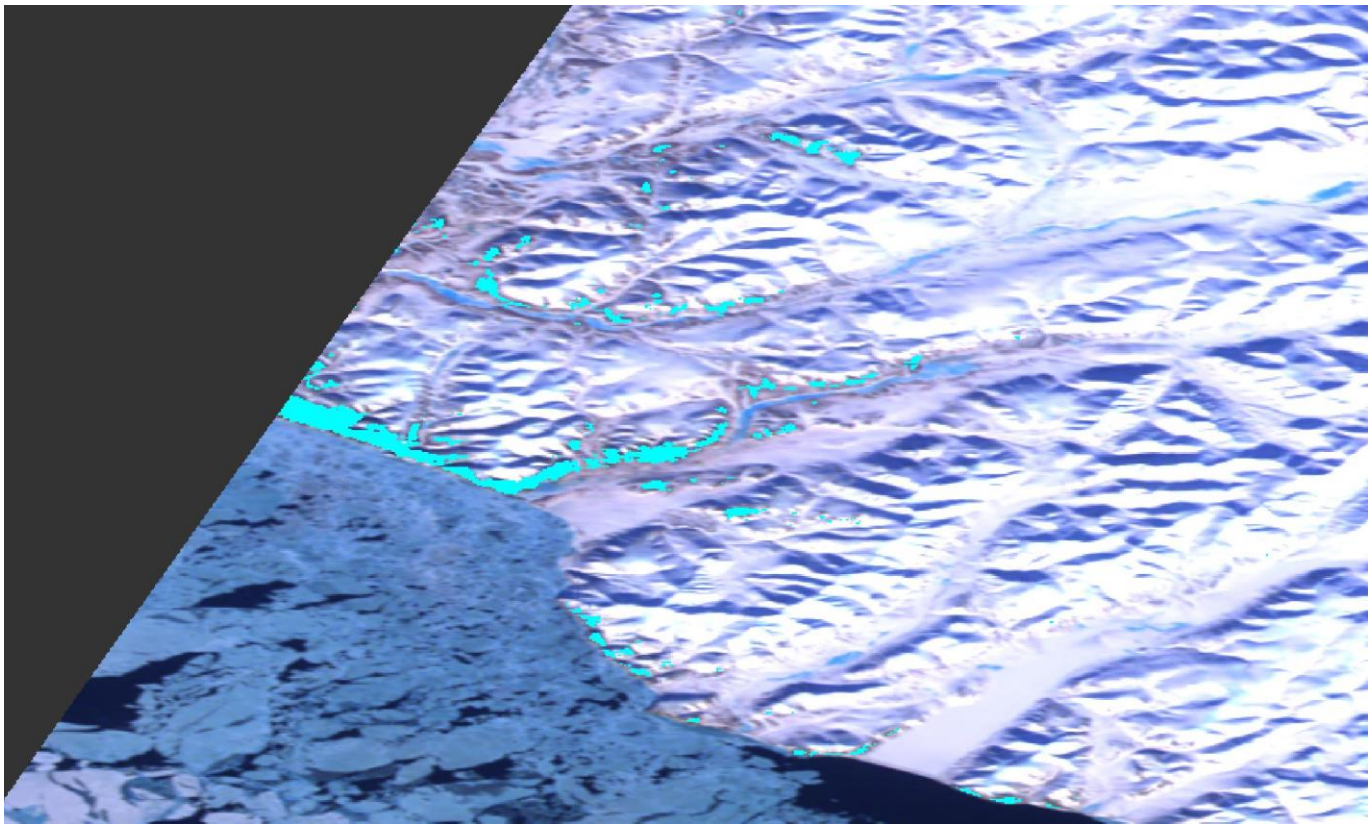
35. PROBAV_S1_TOA_X27Y04_20140321_100M_V101 (East Tibet)
- Well done.

28. PROBAV_S1_TOA_X20Y03_20140321_100M_V101 (Greece)
- That's rather good masking.

Images

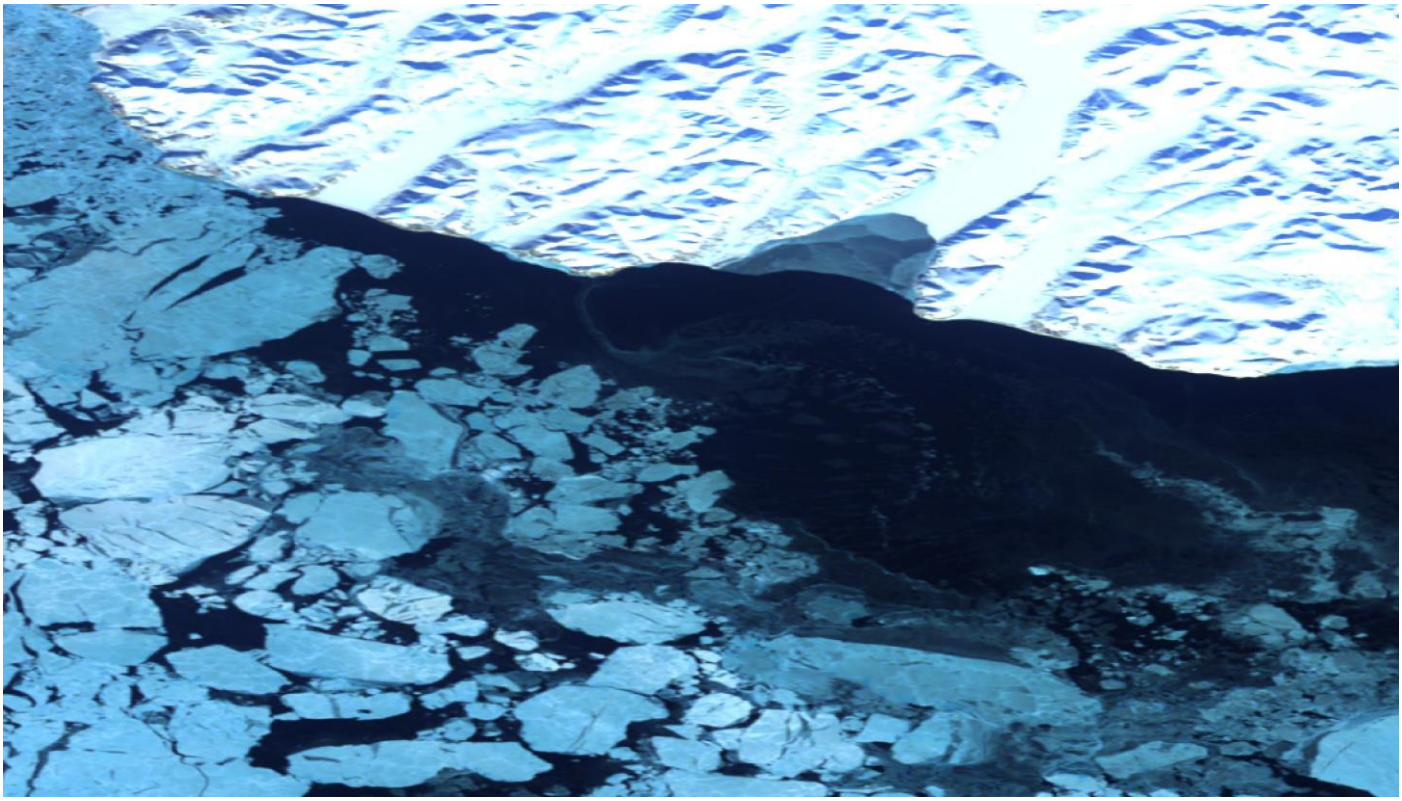
1. PROBAV_S1_TOA_X00Y01_20140321_100M_V101 (Bering Sea in the South of Chukotka)

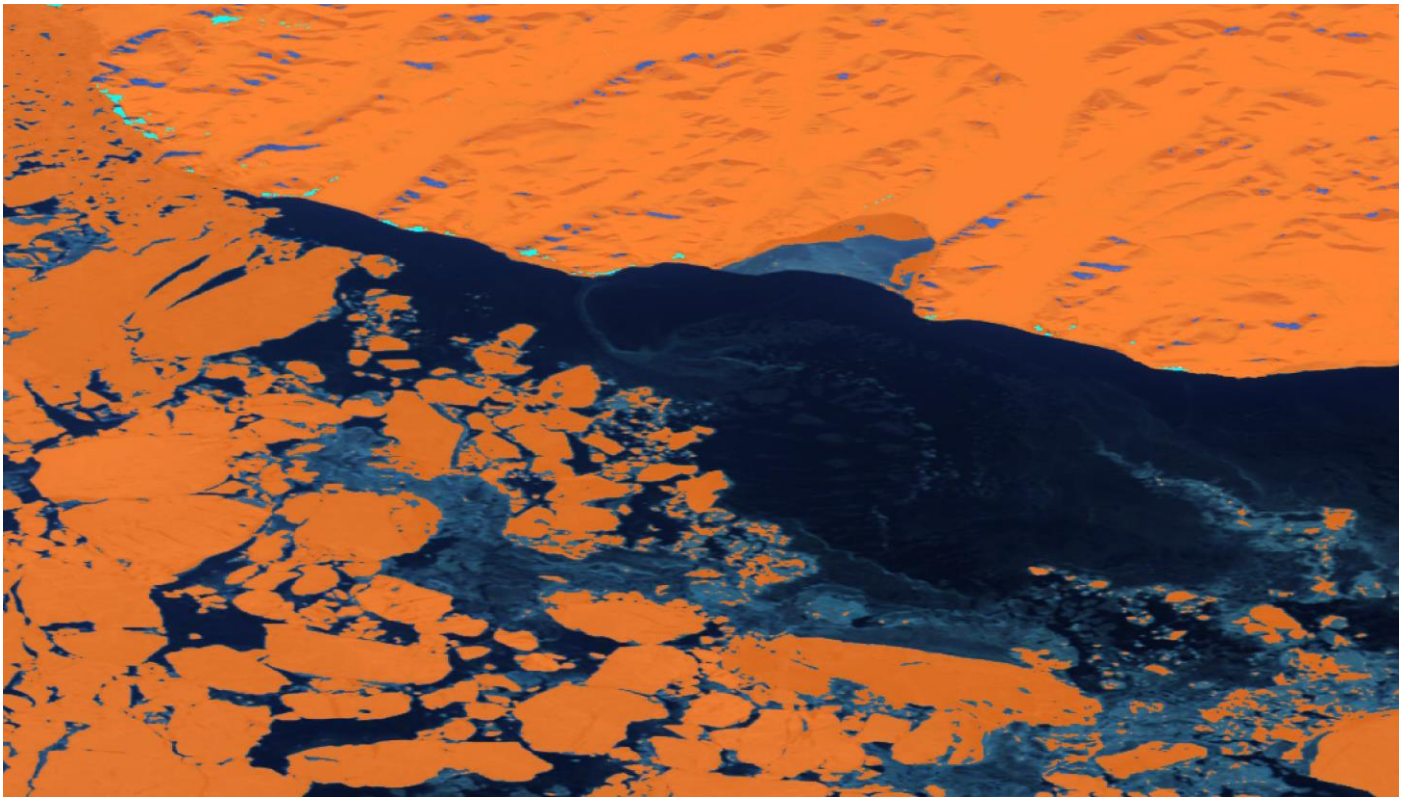




Some of the clear sky rocks that are not covered (or partially covered only) with snow have been incorrectly identified as a cloud covered surface.

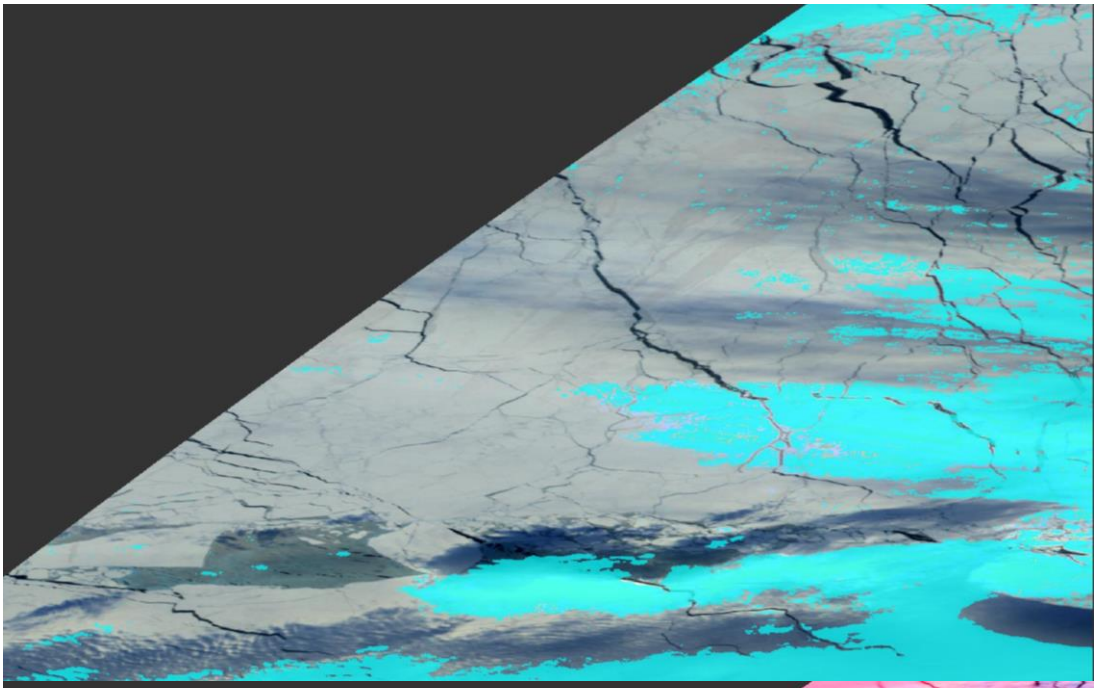
2. The same satellite fragment.





Some of the easily recognizable floating sea ice was not recognized as such.

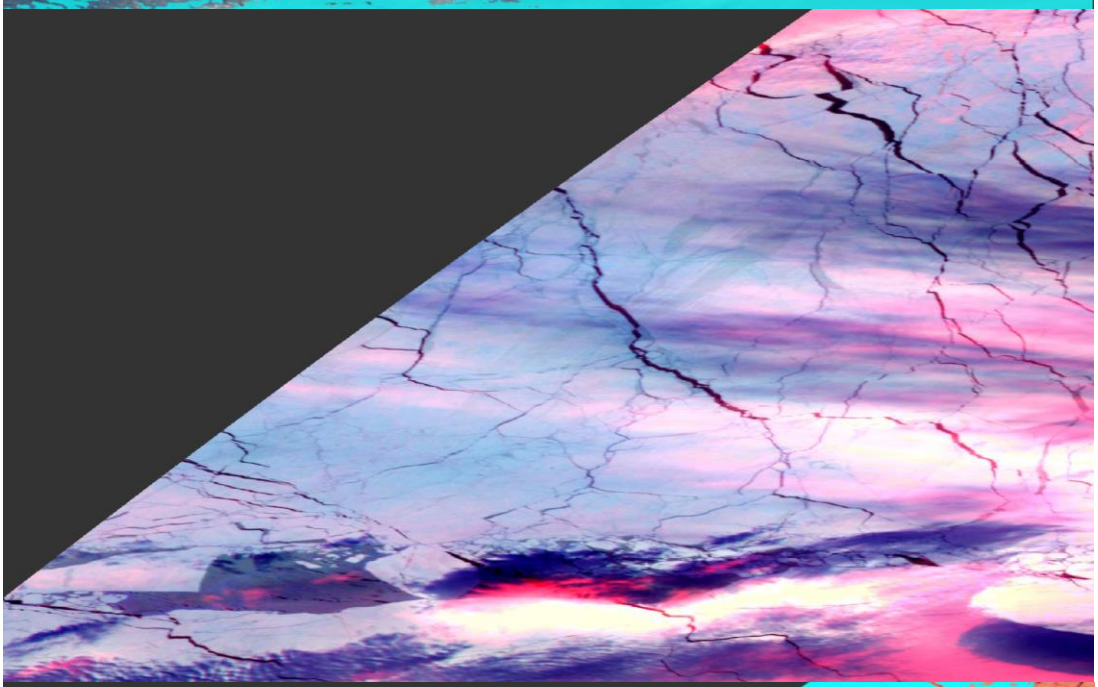
3. PROBAV_S1_TOA_X03Y00_20140321_100M_V101 (Beaufort Sea)



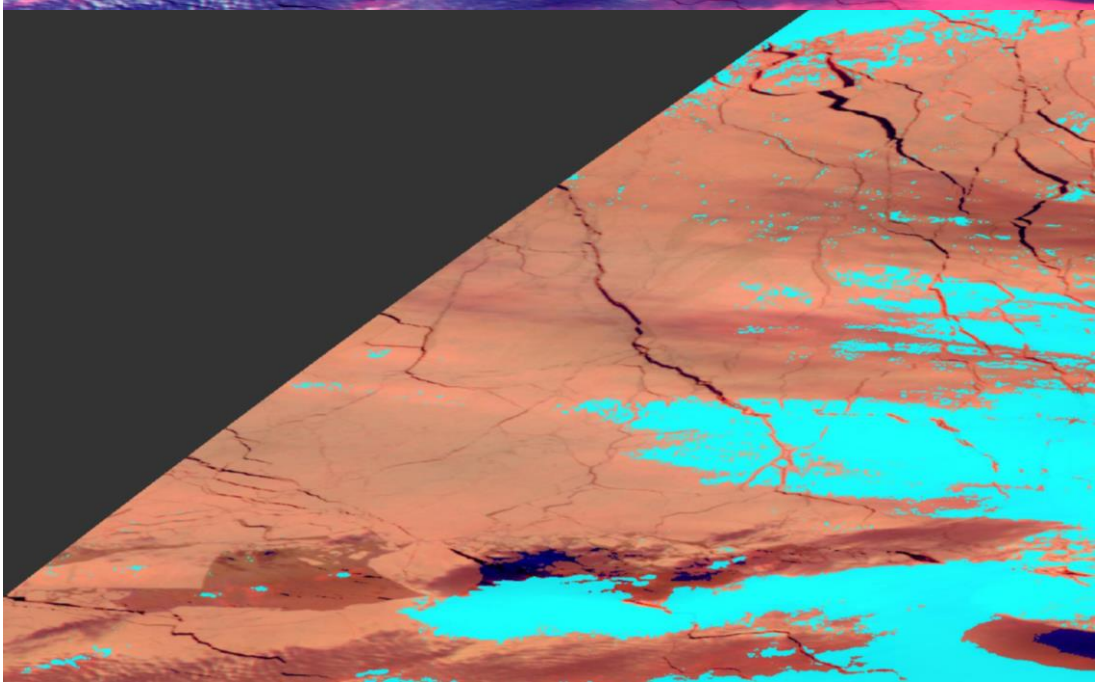
Iced sea is partially covered with clouds. Some of the clouds were not recognized as such. These are thin [cirrus] clouds.

Some clouds cast pretty thick shadows. In extreme cases, such shadowed surfaces are so dark that they were identified as free of clouds and ice. In this case, this is not correct.

RGB1

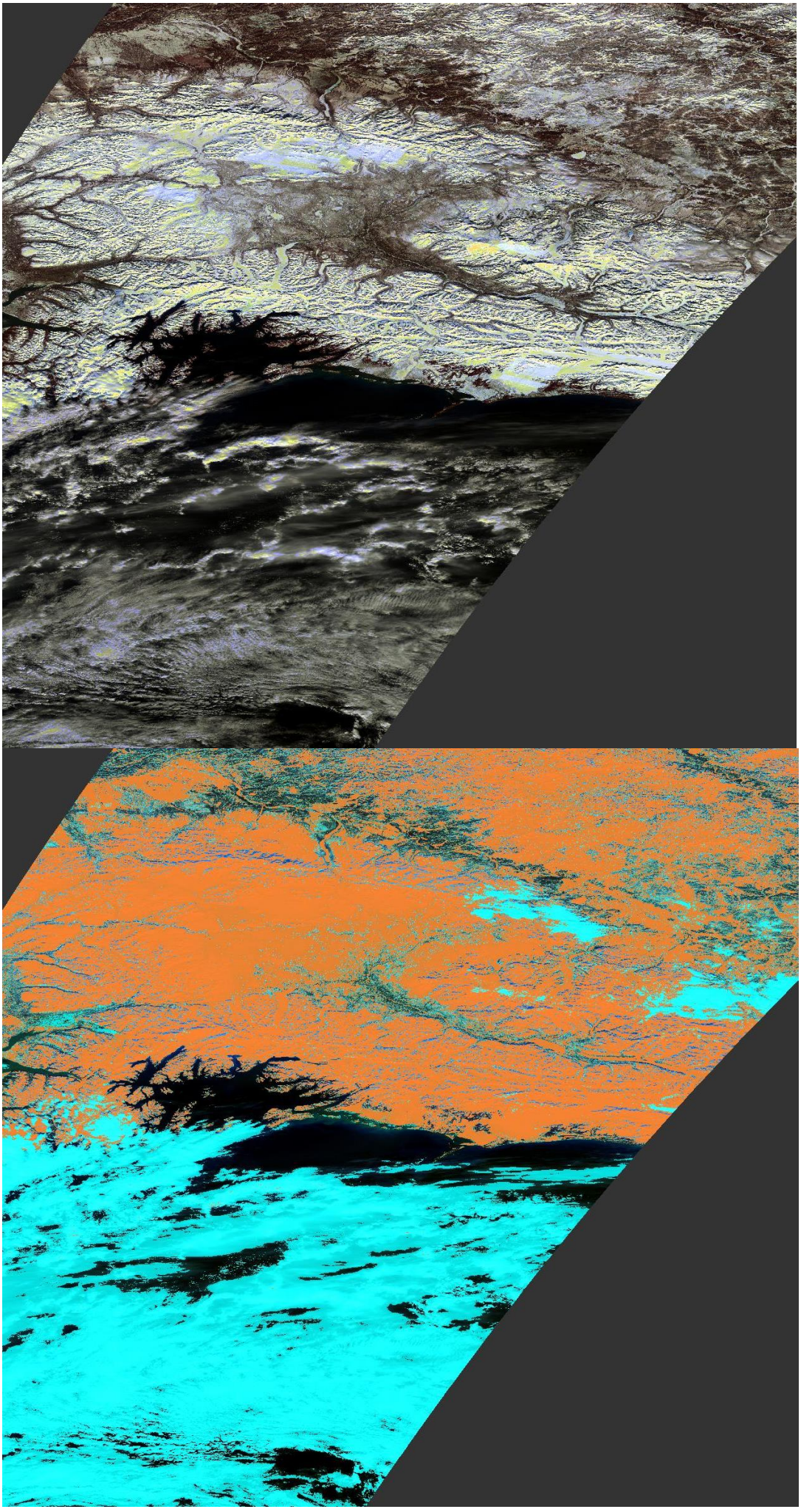


RGB2



Cloud & Ice Mask

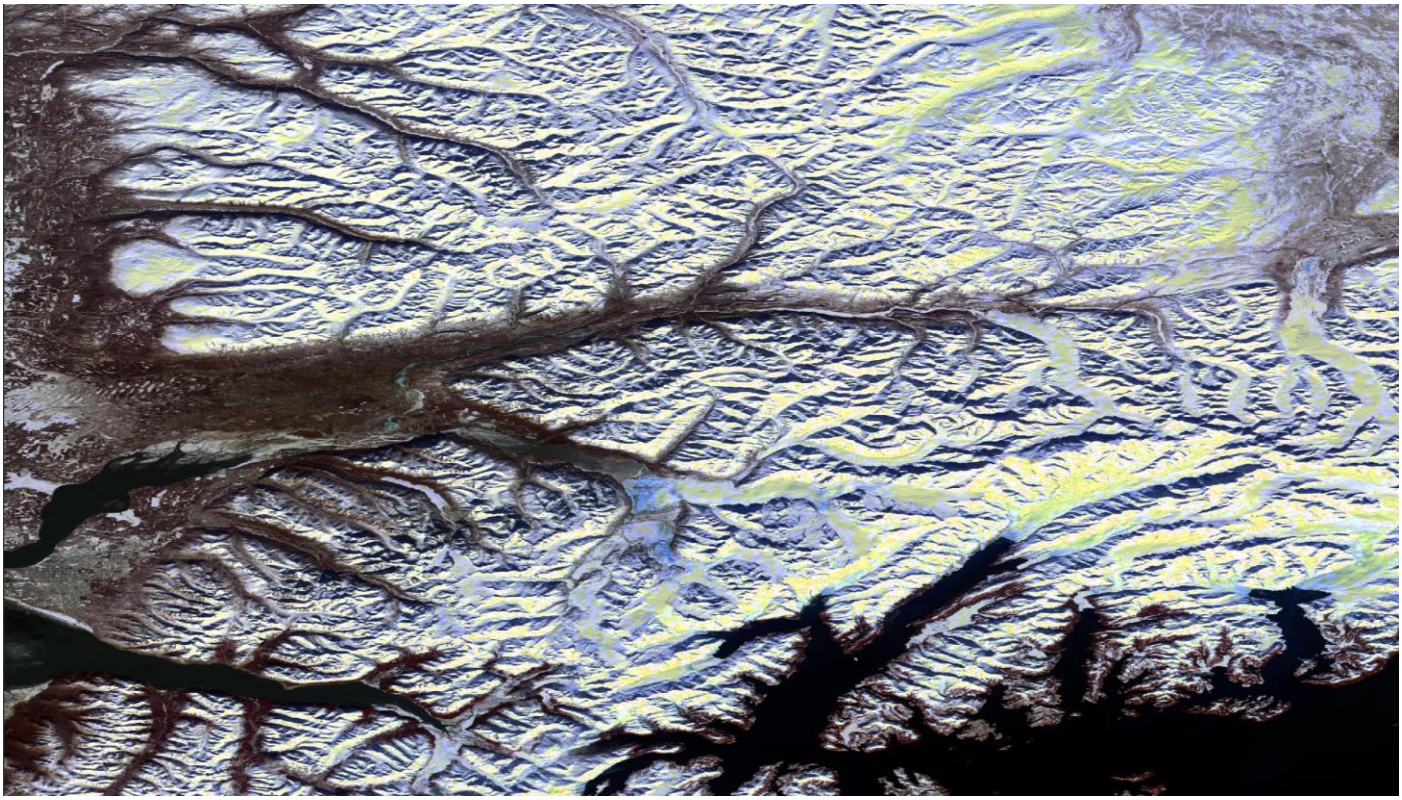
4. PROBAV_S1_TOA_X03Y01_20140321_100M_V101 (Southeast of Alaska, Gulf of Alaska)

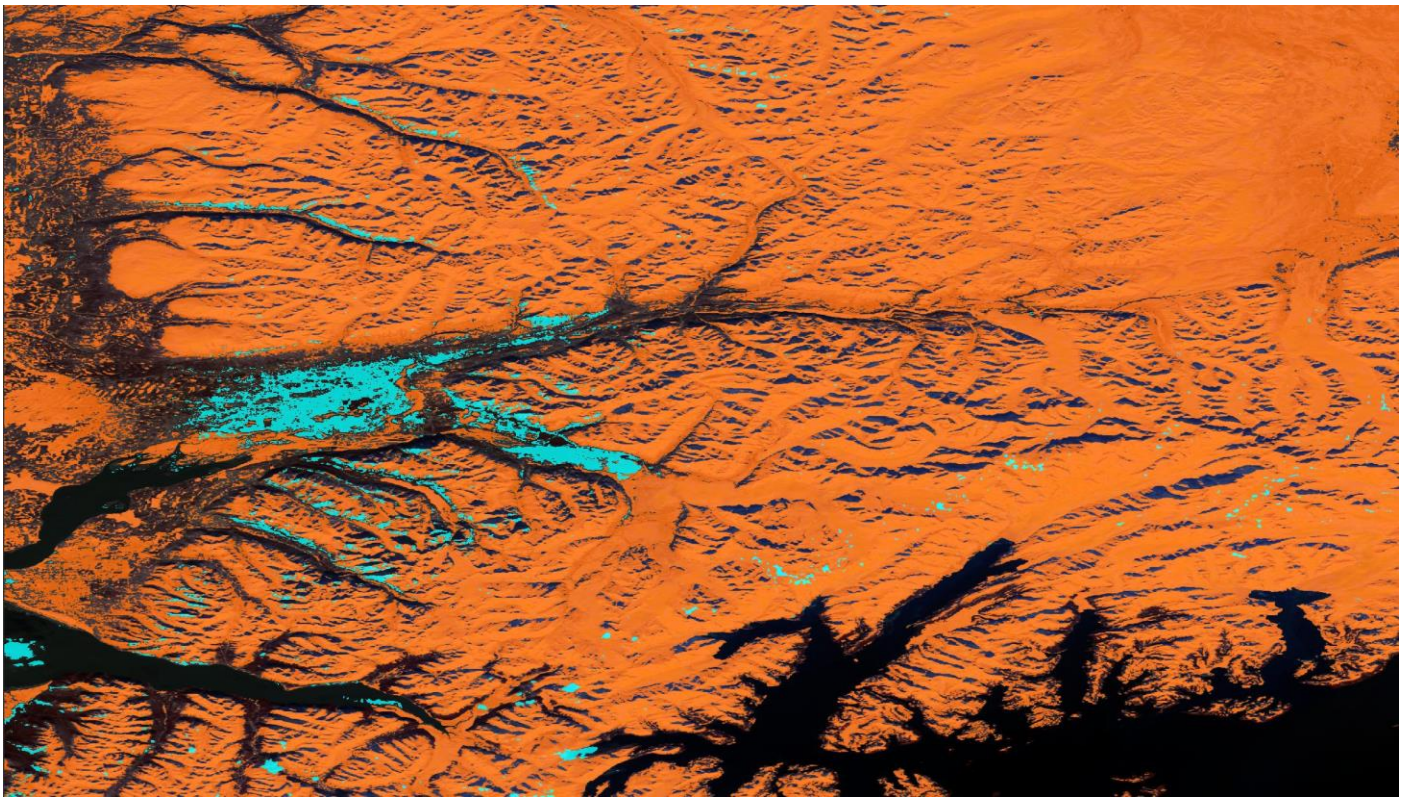


A well done cloud mask and snow mask.

Exceptions are some clear sky valleys, which are partly covered with snow. These valleys are incorrectly identified as cloudy (s. № 5).

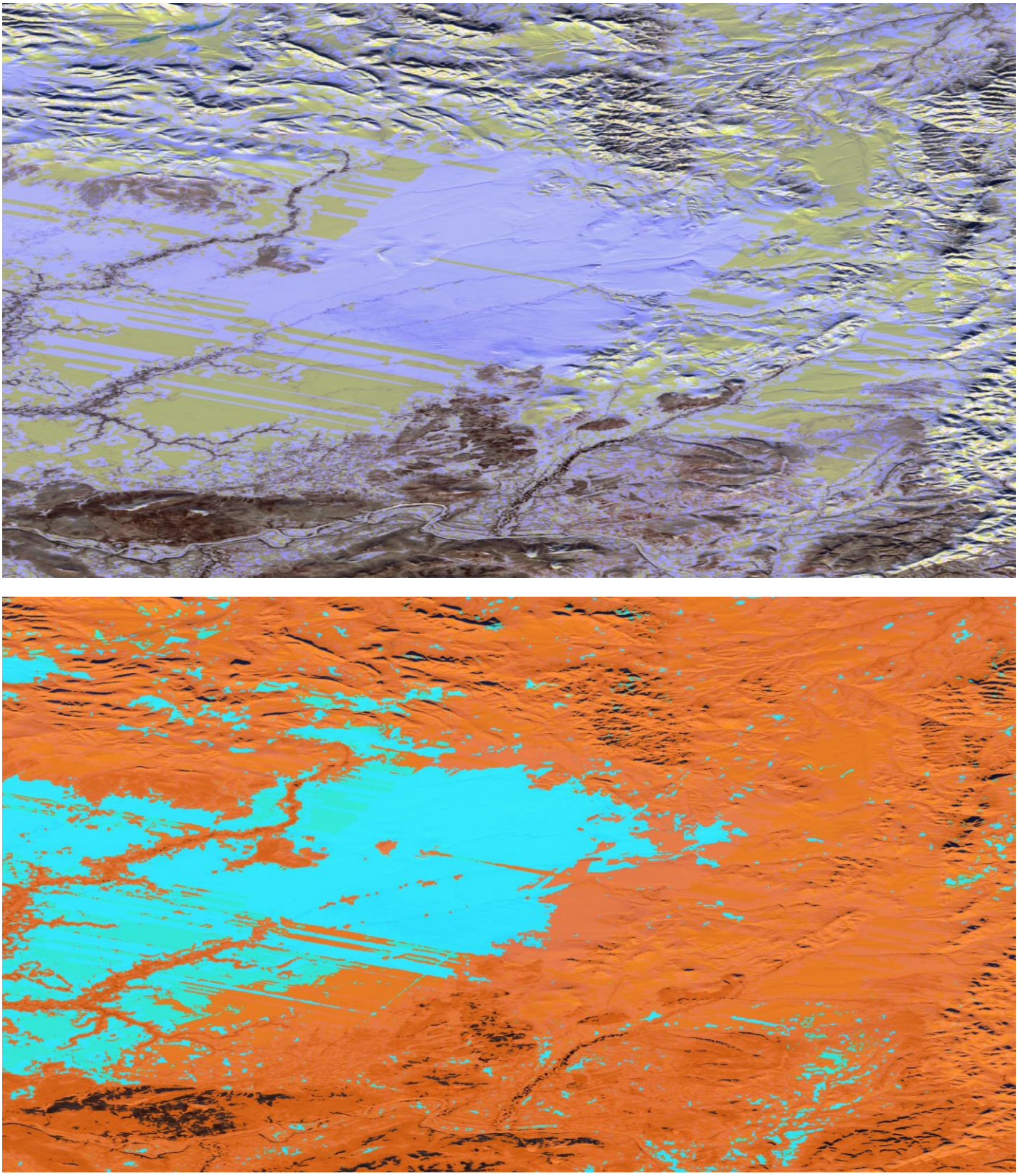
5. The same Fragment (zoomed).





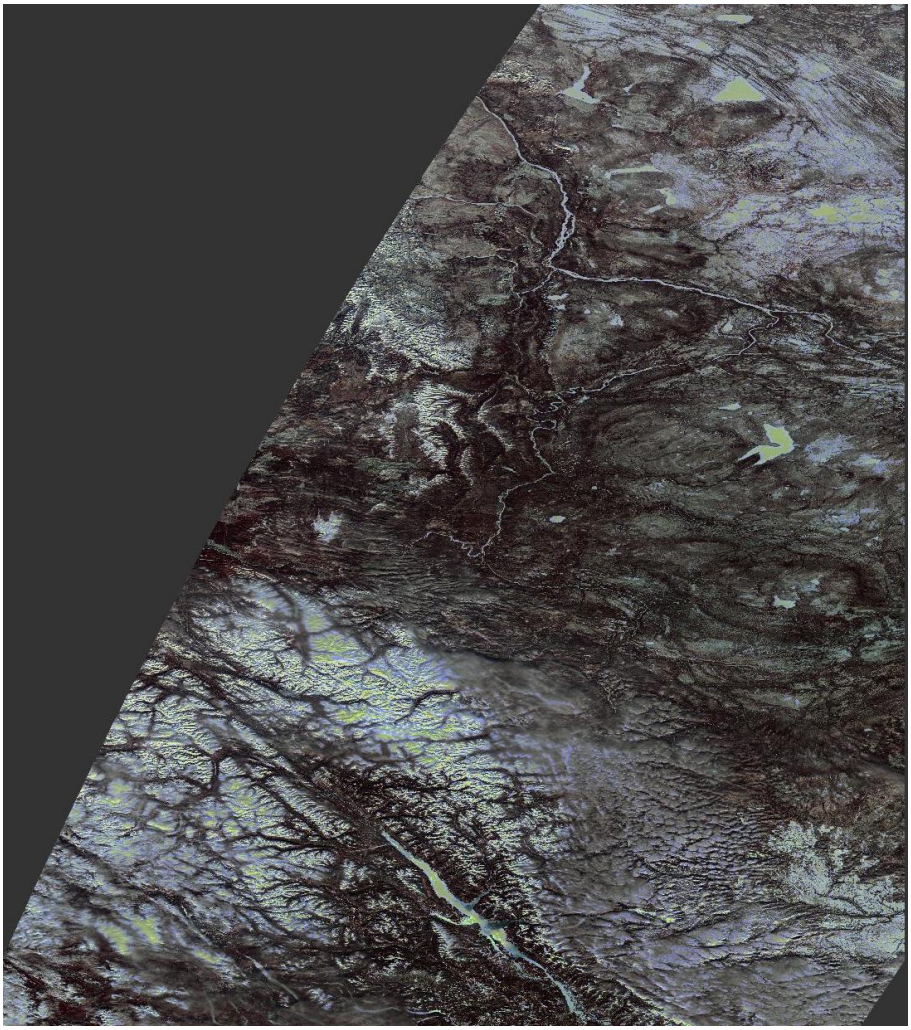
In winter in high latitudes, where the conifers grow, the coniferous forests ground is normally covered with deep snow. The crowns of the trees are usually snow-free or only partially covered with snow. Even deciduous trees without leaves show snow darker underneath. From a satellite point of view, such winter regions seem a little lighter than in summer (due to snowy soils and some trees) but never quite white (like nearby fields). I identify pixels belonging to such regions as partially snow covered pixels.
Here some such pixels are incorrectly identified as cloudy.

6. PROBAV_S1_TOA_X04Y00_20140321_100M_V101 (Northeast of Alaska)



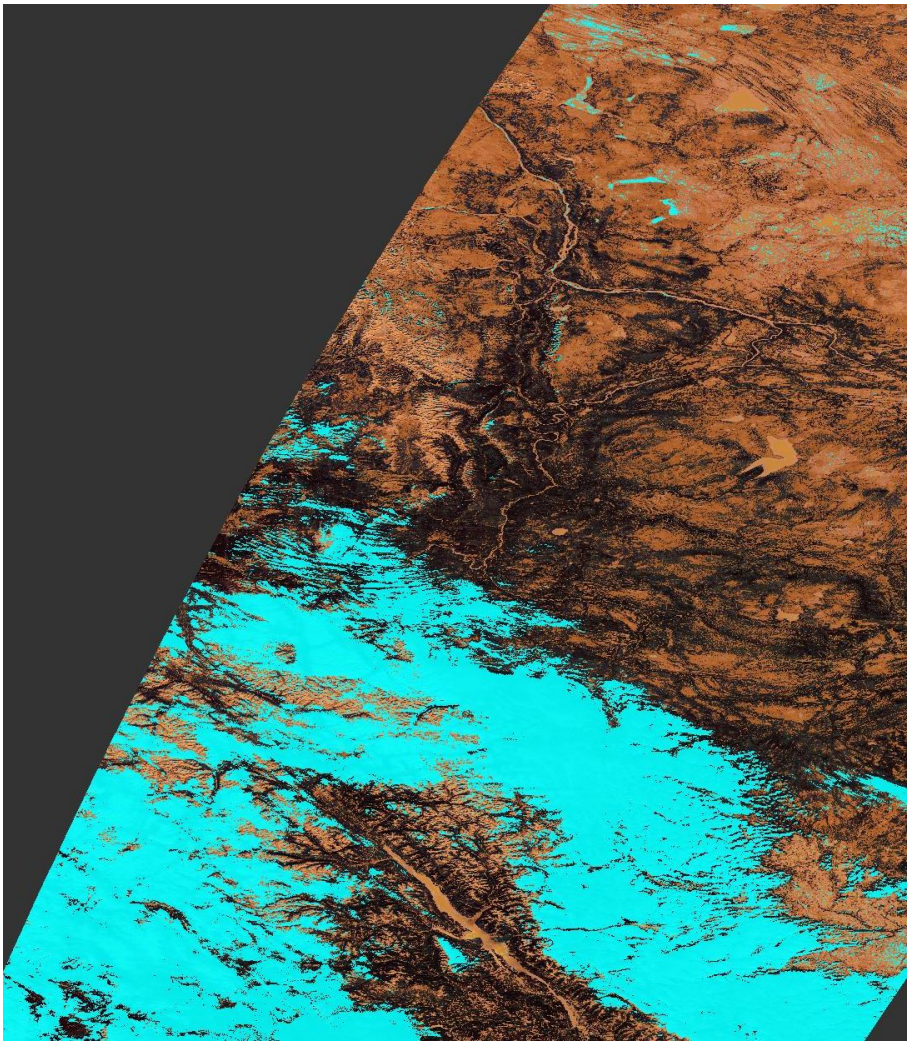
The cloudless snowy/icy surface has been incorrectly identified as cloudy.

7. PROBAV_S1_TOA_X05Y01_20140321_100M_V101 (West of Canada, Yukon, Mackenzie River)



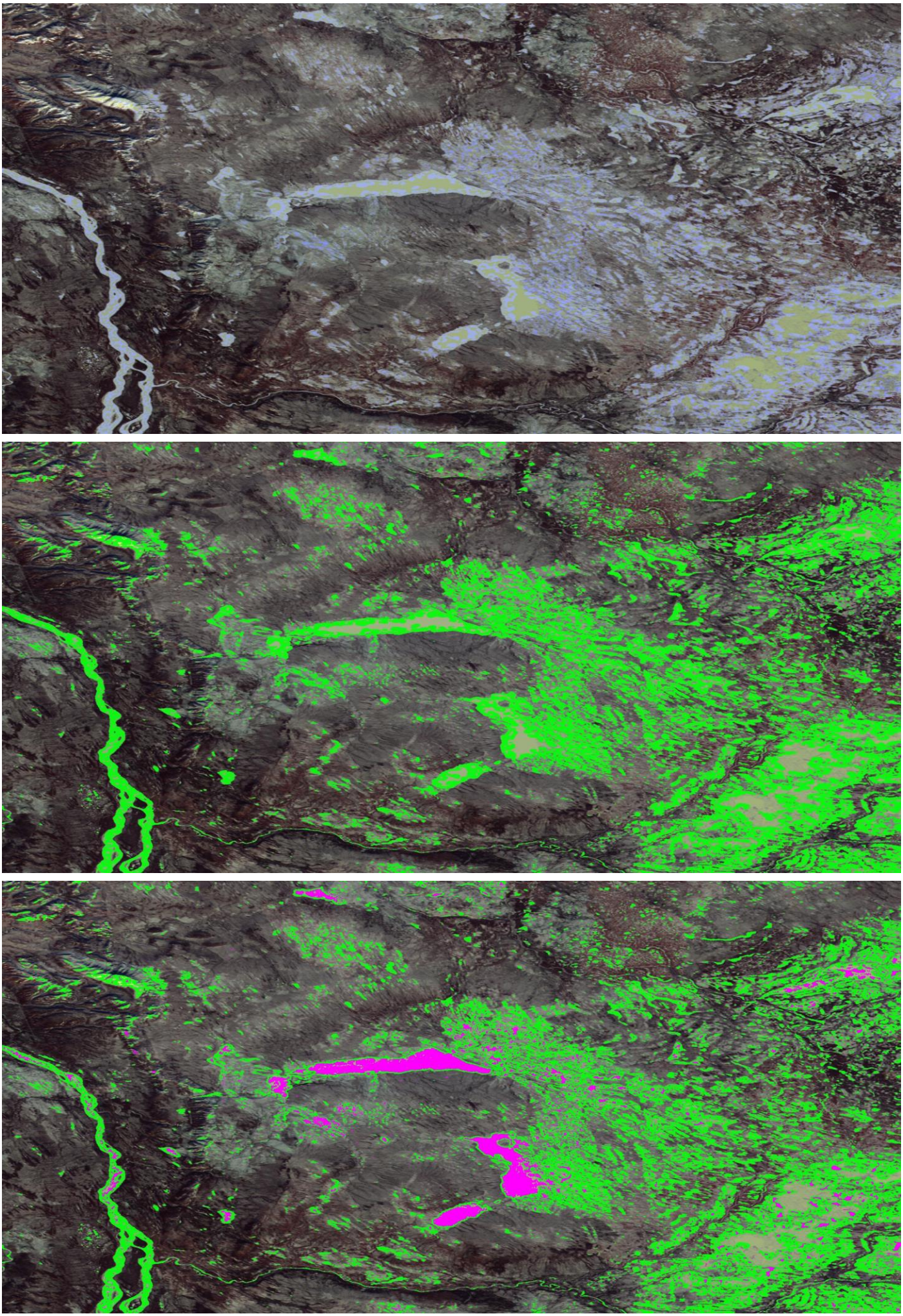
Fairly well resolved cloud/snow masking. Some areas that are in my opinion partially covered with snow are not recognized as such.

Some clear sky icy lakes were incorrectly displayed as cloudy. This may be due to the installed "SM_FLAGS_GOOD_BLUE" mask, which appears as "not good" in some lakes (s. comments to № 5).

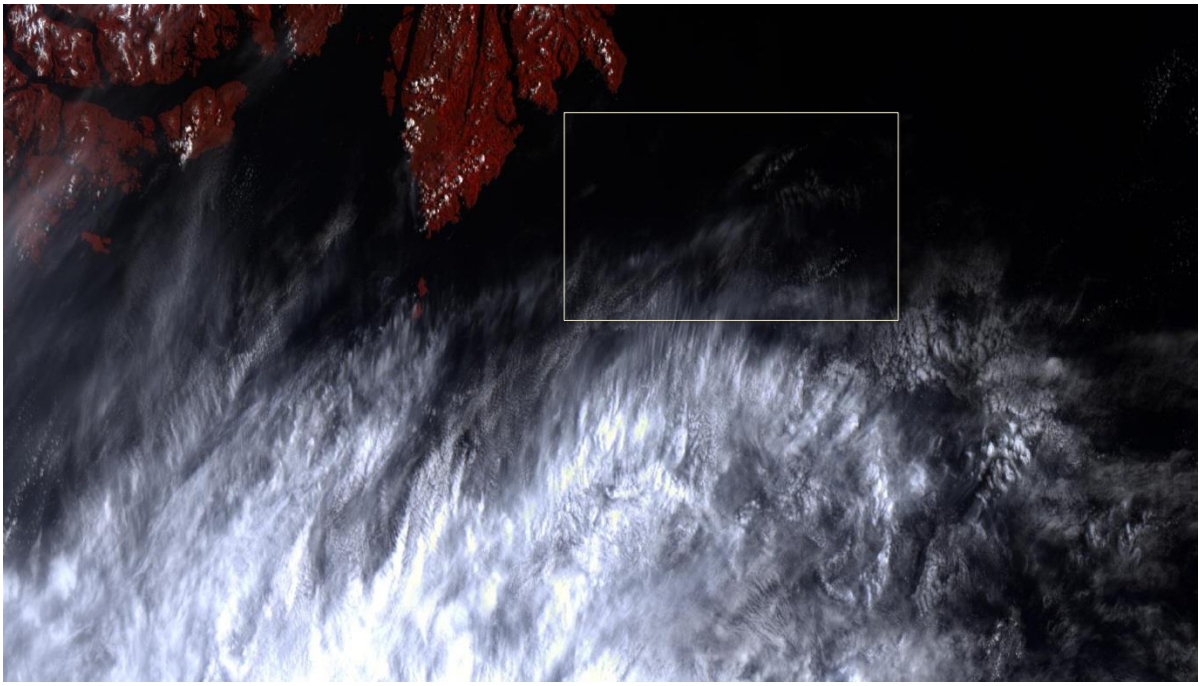


8. The same Fragment (zoomed).

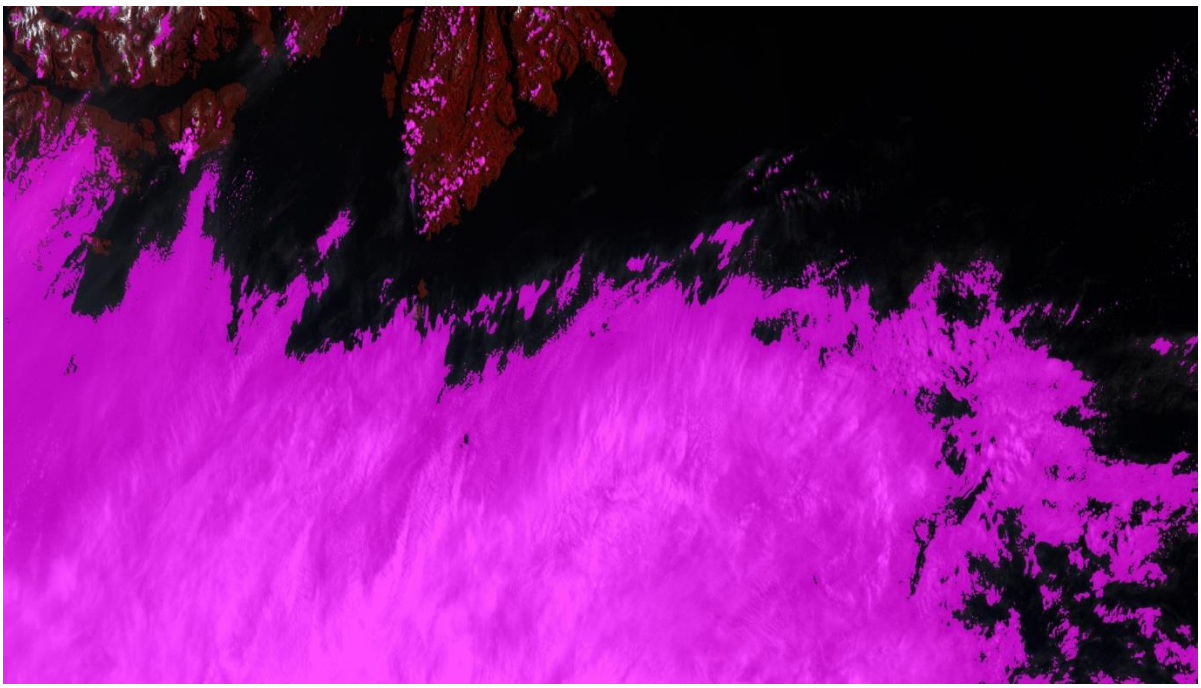
🡻 Description to № 8 (next page).
The icy lakes just mentioned, which have been incorrectly identified as cloudy areas.
Pictures from top to bottom:
RGB fragment
RGB with the "SM_FLAGS_GOOD_BLUE" mask - **GREEN**.
RGB with the green "SM_FLAGS_GOOD_BLUE" mask and the pixels that have been wrongly considered “cloudy” - **ROSE**. 🡻



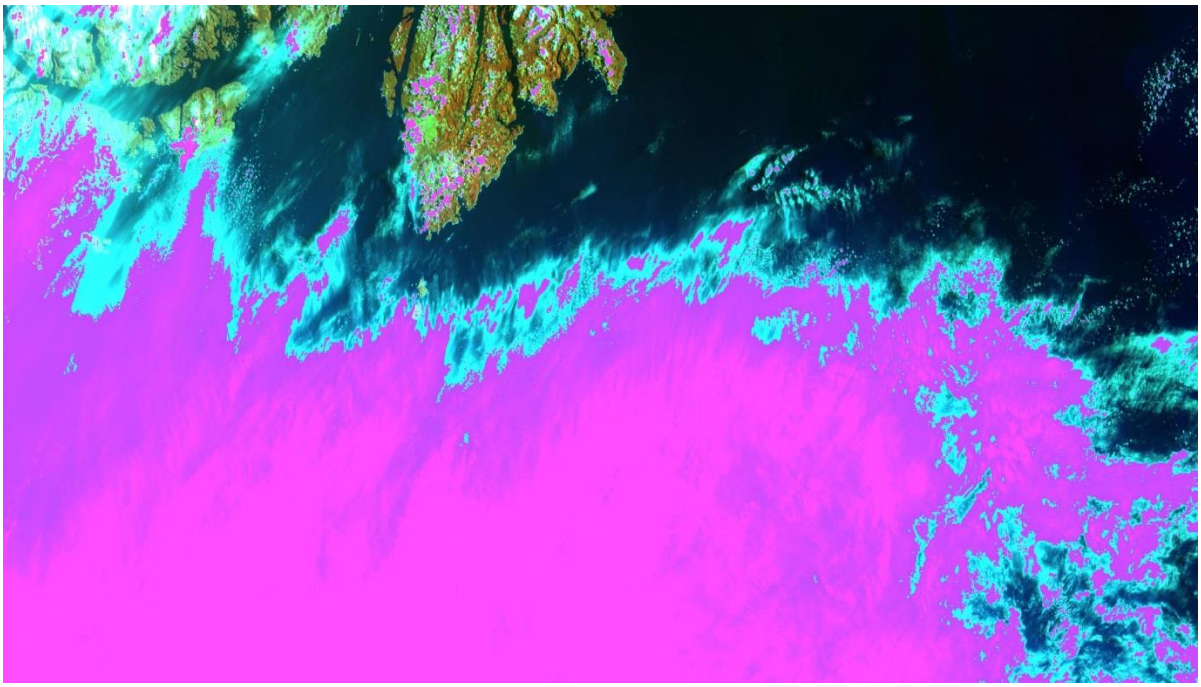
9. PROBAV_S1_TOA_X05Y02_20140321_100M_V101 (Northeast Pacific in the West of Vancouver Island)



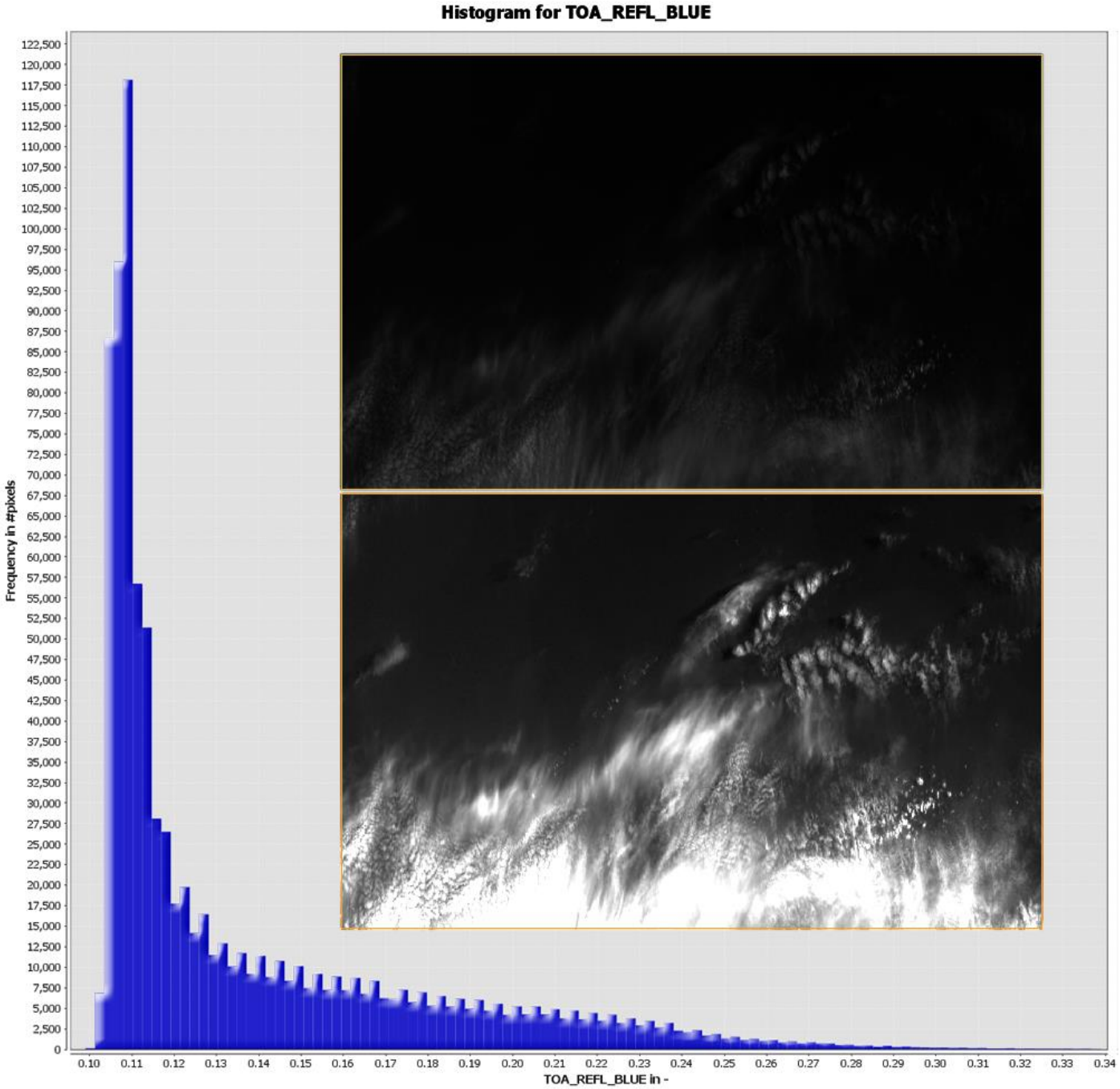
a



b

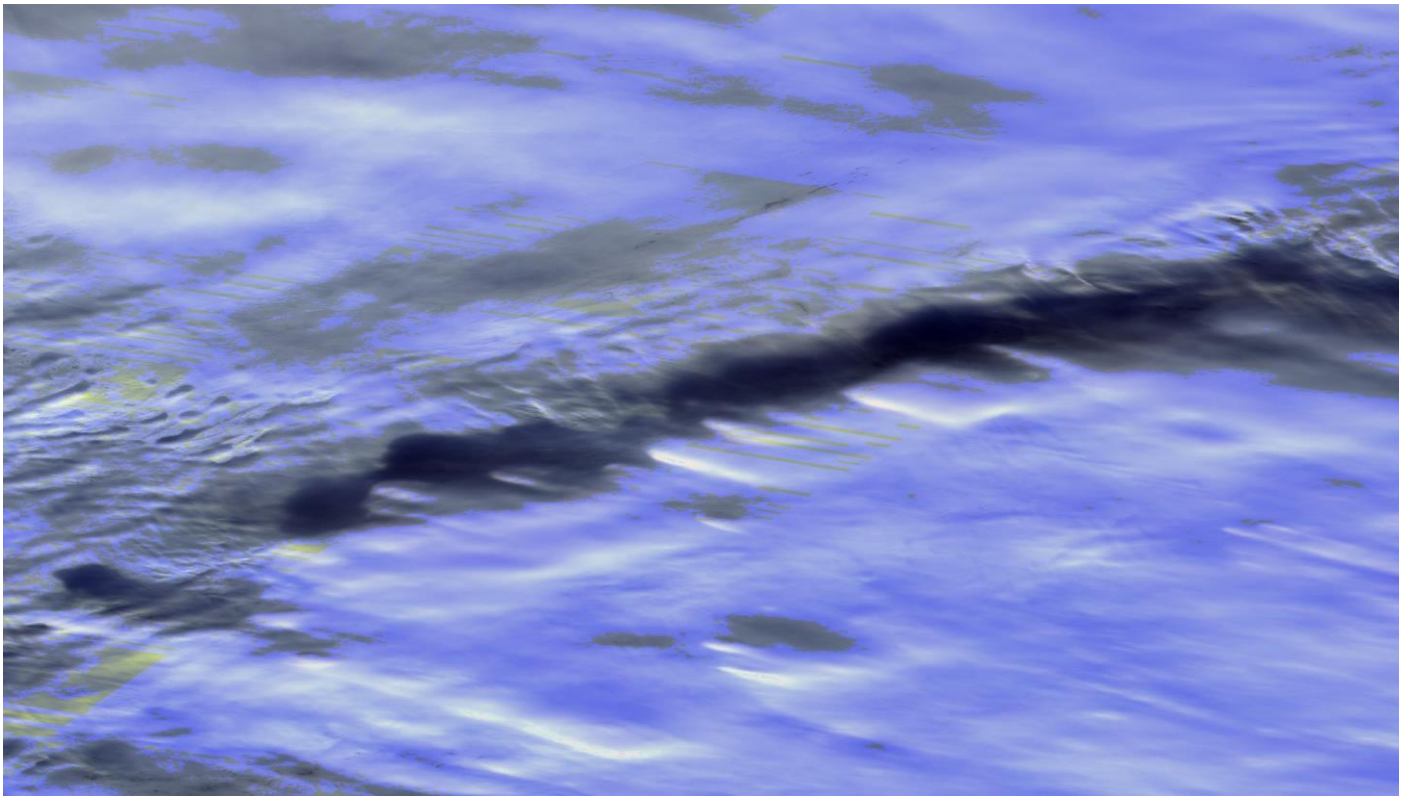


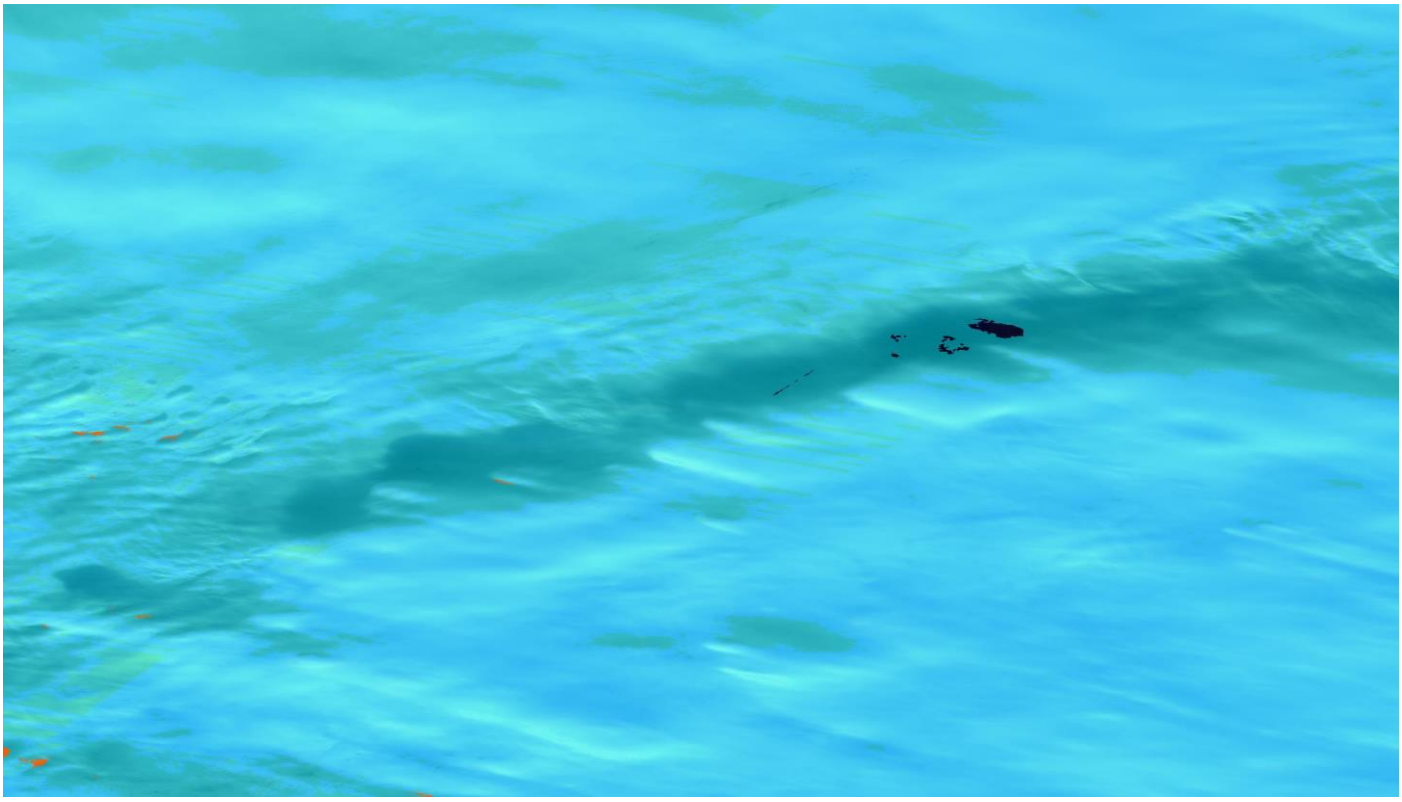
c



Description to № 9 (this & previous pages).
Very thin, semi-transparent clouds above the water but also above the land are normally not noticed and are therefore not displayed with a cloud mask.
It is a very old and familiar story. I would suggest skipping from one-dimensional to two-dimensional detection methods in such cases (and especially above water and other homogeneous surfaces). In the first case, information from one pixel is used (data from existing channels, geographic coordinates, time, auxiliary astronomical data, satellite position, position within the scan line, etc.) In the second case, data from the surroundings of the examined pixel is also used.
Here is a sketch of two-dimensional cloud detection method. As an example, an area is shown that lies on the edge of a cloud and naturally consists of very thin clouds and underlying surface. Such fragment is shown on the picture 9 "a" (also shown on the top here; below - strongly contrasted picture), where there is surely a homogeneous surface (in our case water). The histogram of the area detects a peak (that is a lot of almost the same reflectance, and they are dark, so rather water) and an extended, outstretched "tail", which presents lighter pixels with different intensities. Obviously they are most likely pointing to the clouds. The threshold around the value of 0.12 can show a local limit (valid only for the examined area), of which the reflectance values, which are larger than this local value, indicate clouds rather than cloud-free water. And they absorb some radiation that goes up from water.
However, such a small part of the not taken into account radiation may not be as important for further research and therefore irrelevant.

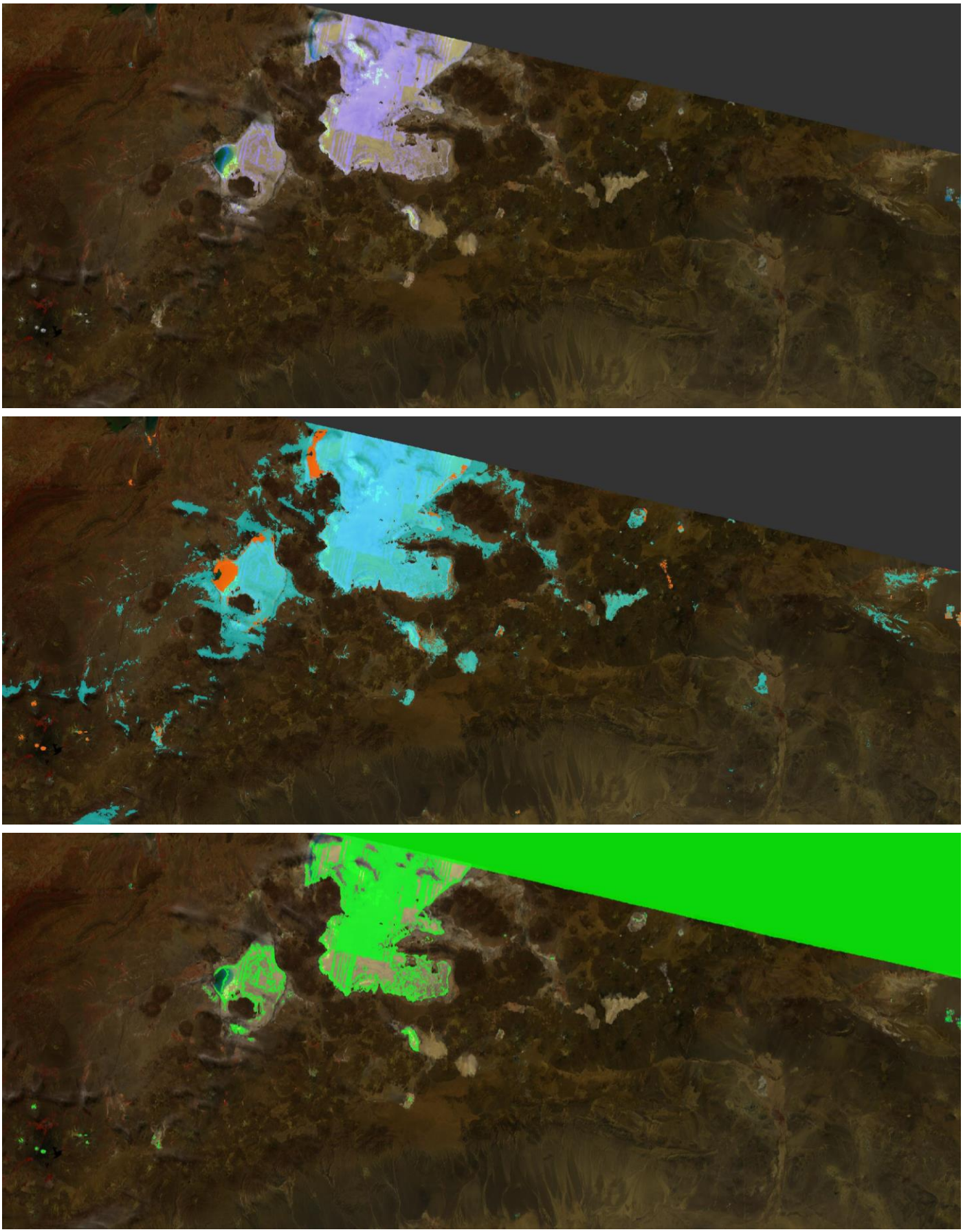
10. PROBAV_S1_TOA_X06Y00_20140321_100M_V101 (Victoria island, Canada Arctic Archipelago)





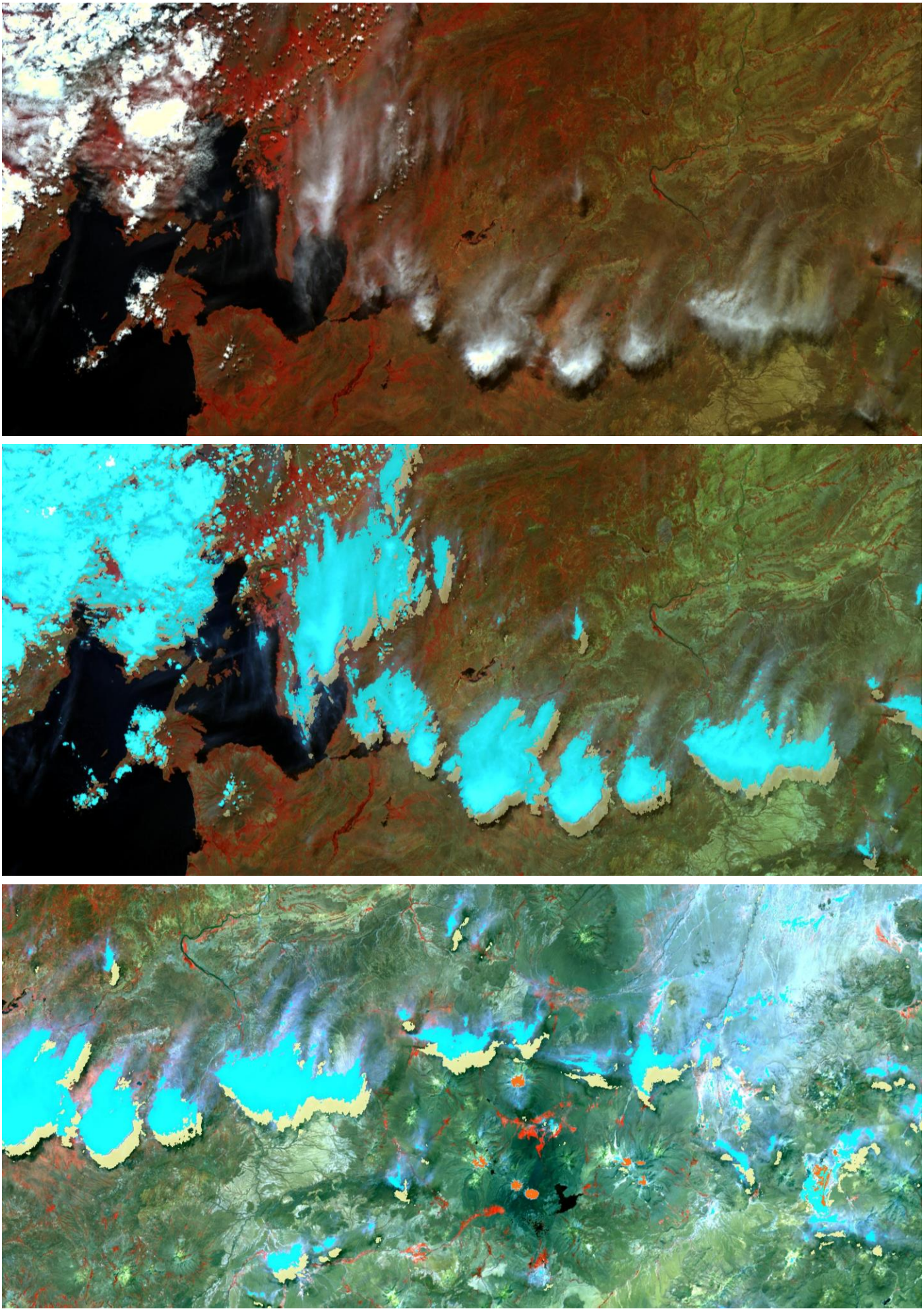
Very thick cloud shadow above the clouds has been recognized as a cloud. A small black spot on the lower image should indicate cloud-free pixels. But most likely the shadow is just too thick there and the pixels too dark at this point. The doubts appear when you look at the two-dimensional cloud structure as a whole. In such cases (small regions (i.e. two-dimensional objects) completely in cloud shadows, surrounded by clouds) I would at least mark it as "questionable".

11. PROBAV_S1_TOA_X11Y09_20140321_100M_V101 (Salar de Uyuni, Bolivia)



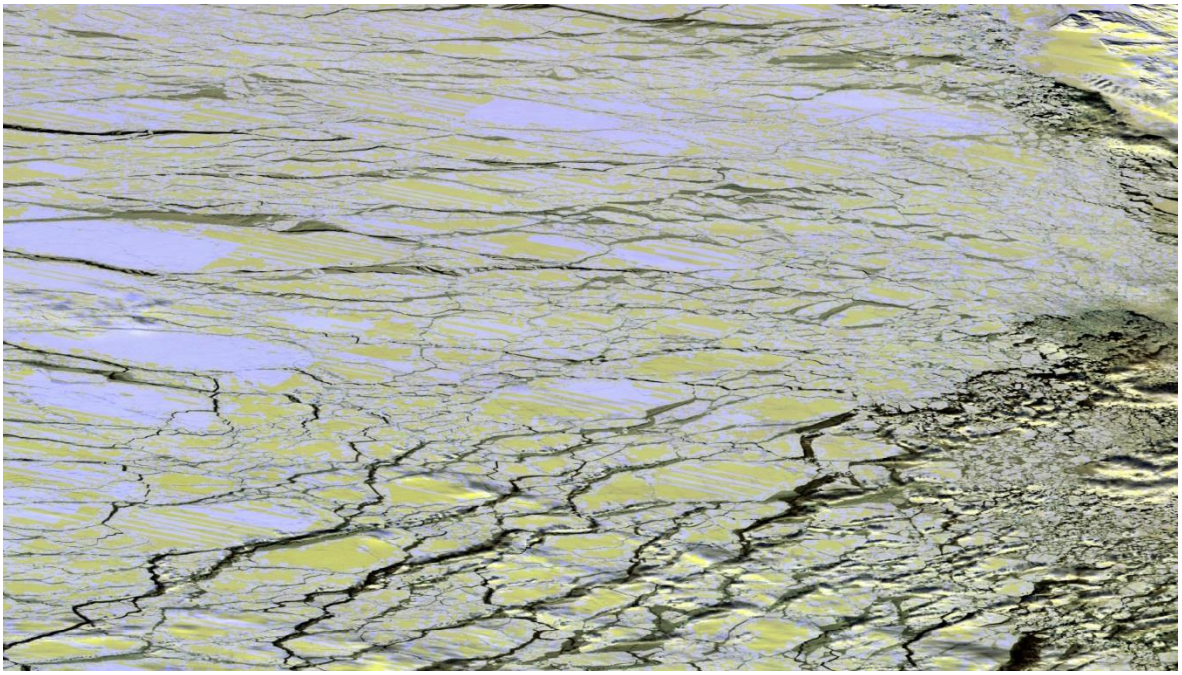
Salt lake lying under the clear sky was incorrectly identified as a cloud covered region. The moist areas that show water not covered with salt are incorrectly identified as ice. This is a method error.
Below is "**NOT**_SM_FLAGS_GOOD_BLUE" mask presented.

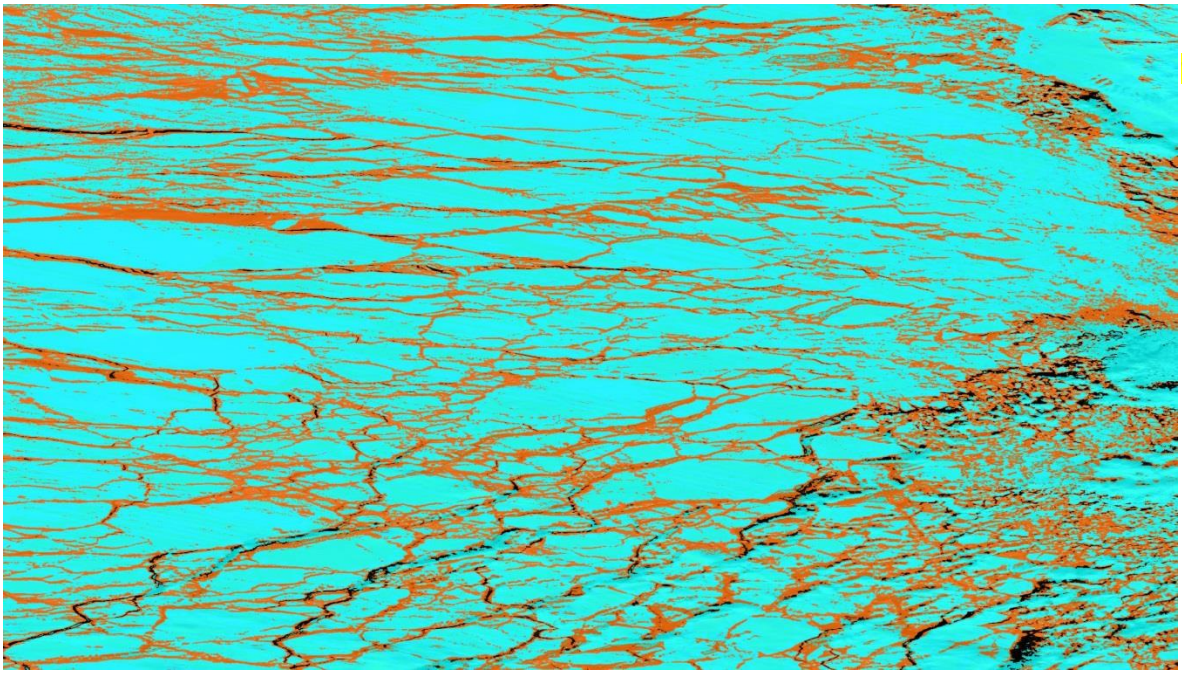
12. The same fragment. (Bolivia, in the south of Titicaca)

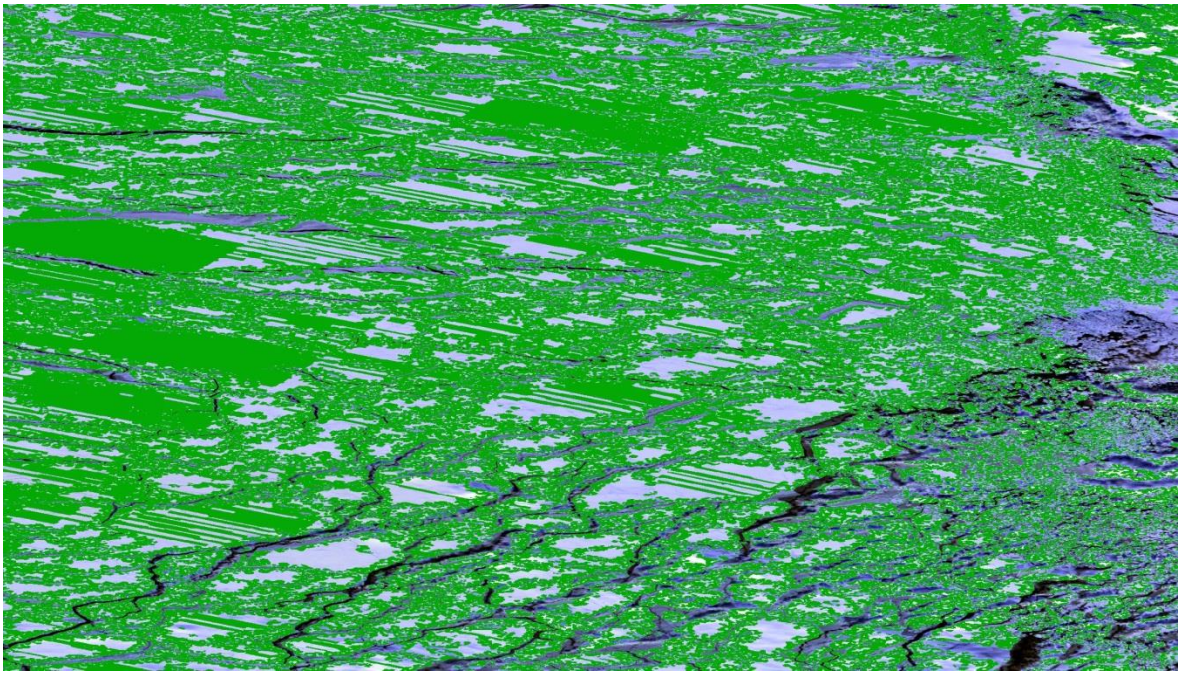


Cloud, cloud shadow, ice. Some very thin semi-transparent clouds were not identified as such.

13. PROBAV_S1_TOA_X12Y00_20140321_100M_V101 (Davis Strait, West Greenland)



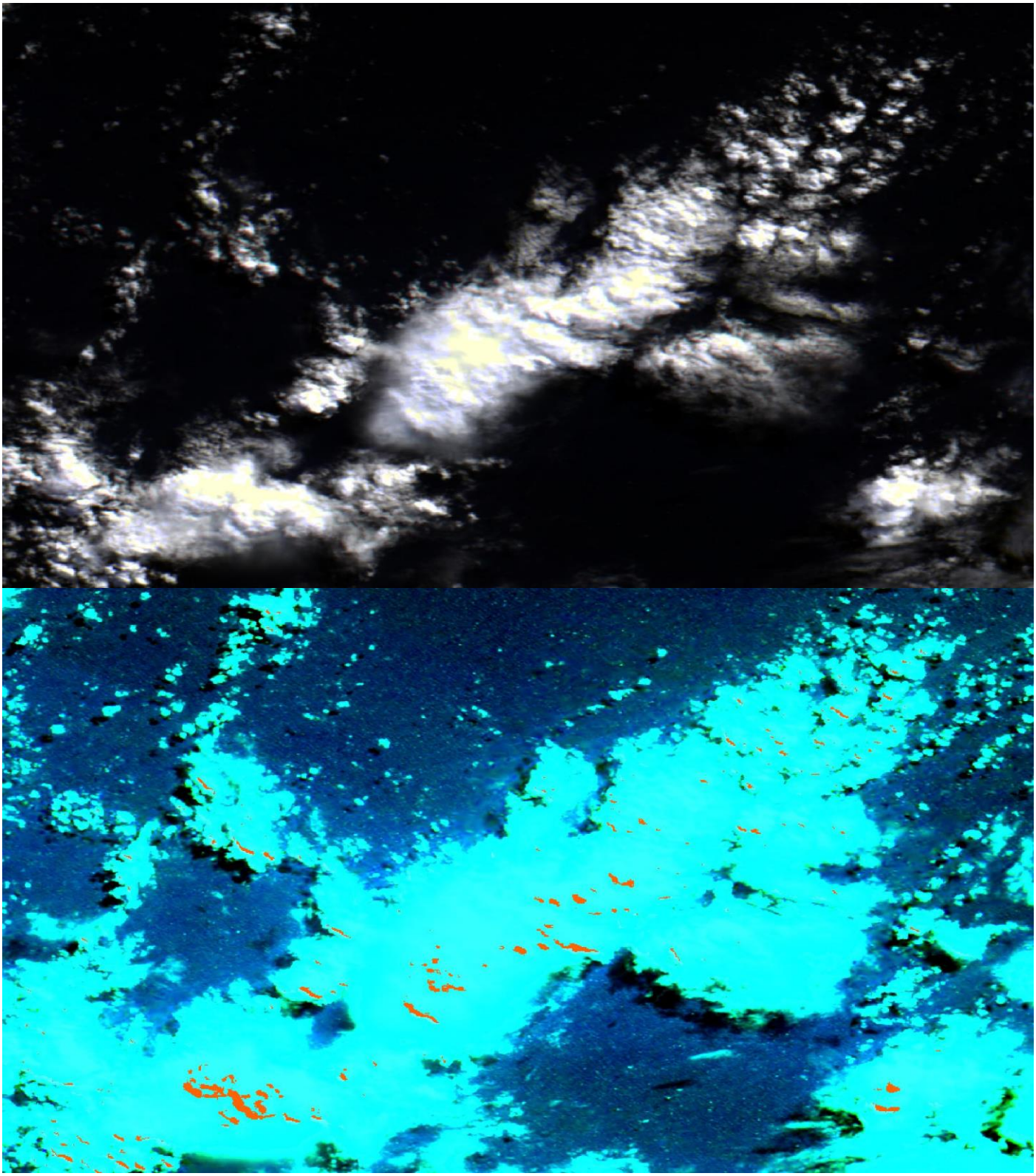




The clear sky floating ice is masked as cloudy.
The ice free (and cloud free) water, cracks between ice floes, was masked as ice.
Both are not correct.

Maybe that's because of the mask "**NOT**_SM_FLAGS_GOOD_BLUE" (**green** picture at the bottom).

14. PROBAV_S1_TOA_X12Y12_20140321_100M_V101 (South Atlantic in the Northeast of Falkland Islands)

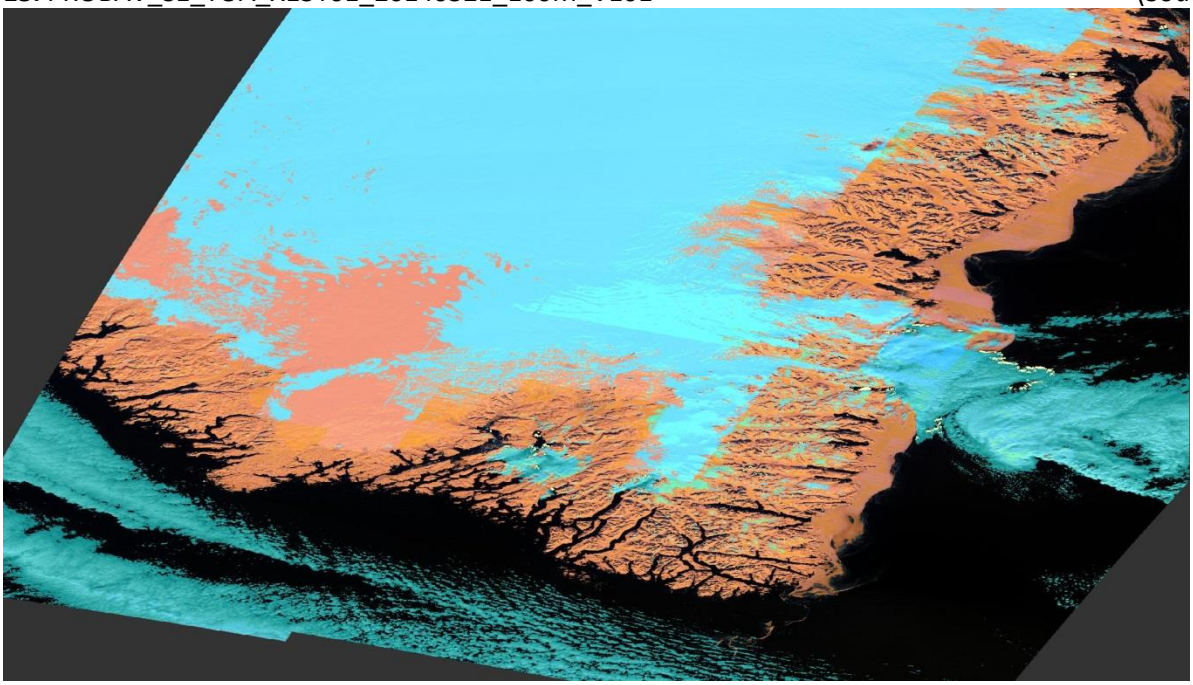


Some very bright and pre-masked cloud pixels were indicated as ice. Below - a strongly contrasted picture with masks. No shadows were found; maybe the water is too dark. However they can be seen when contrasting.

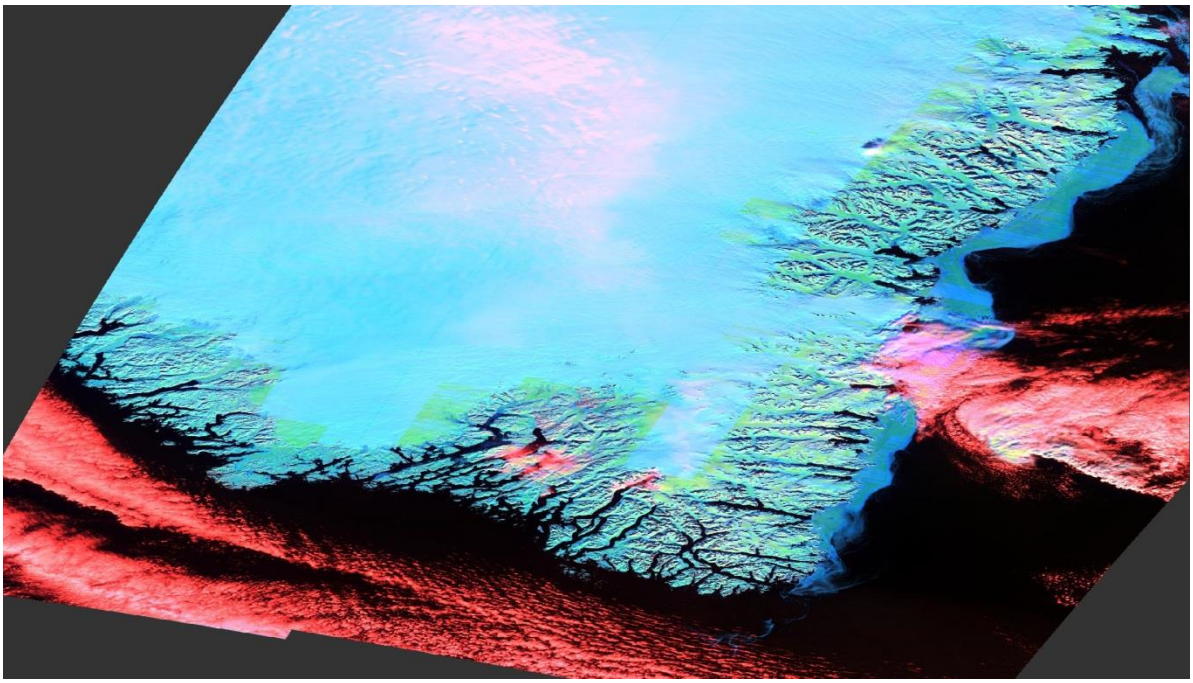
Description to № 15 (next page). ➔

A large amount of continental ice lying under the clear sky on the high plateau of Greenland is incorrectly identified as cloudy. Maybe that's because of the mask "**NOT**_SM_FLAGS_GOOD_BLUE" (**green** picture at the bottom [c]).

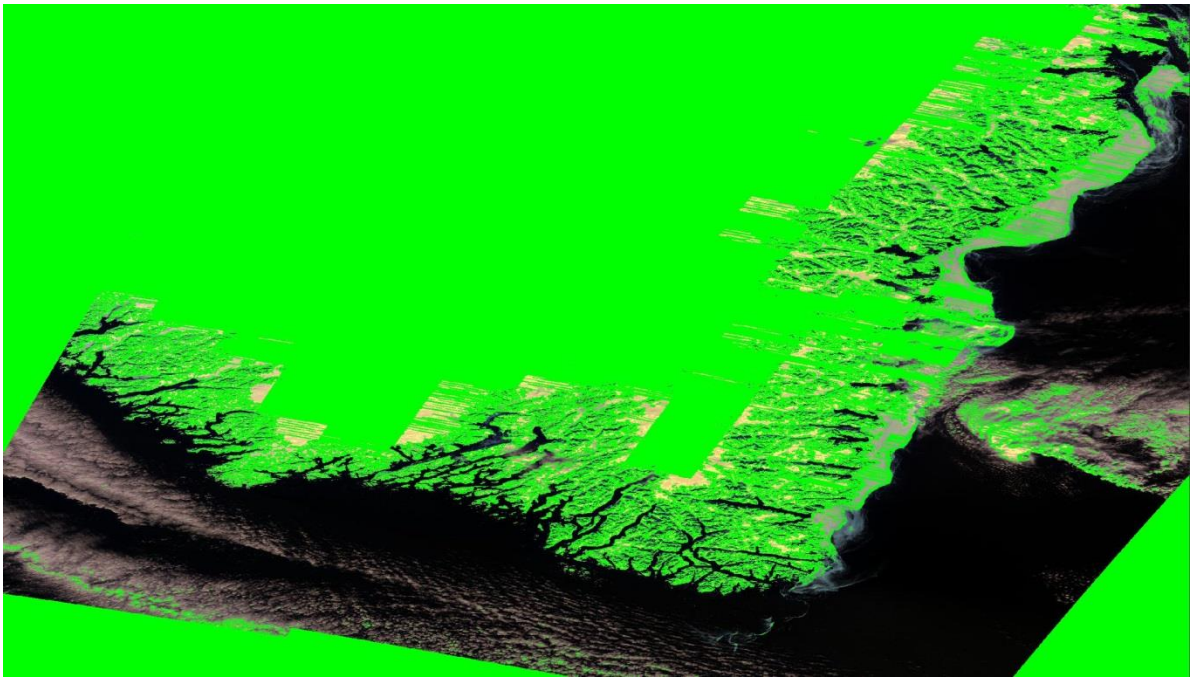
15. PROBAV_S1_TOA_X13Y01_20140321_100M_V101 (South of Greenland)



RGB1

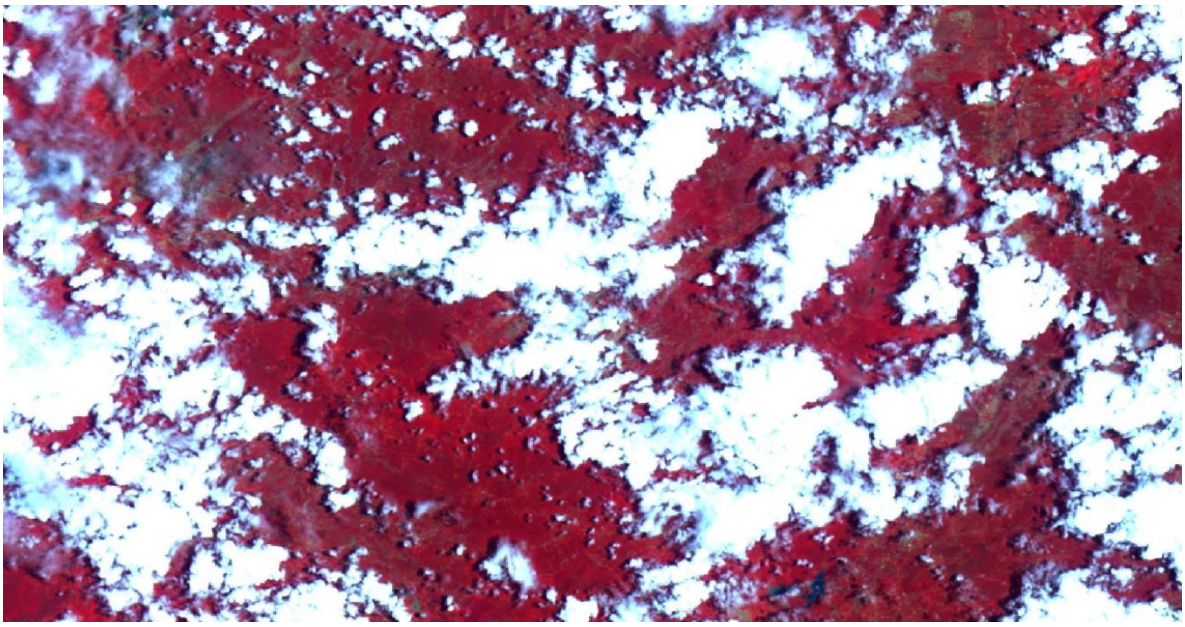


RGB2

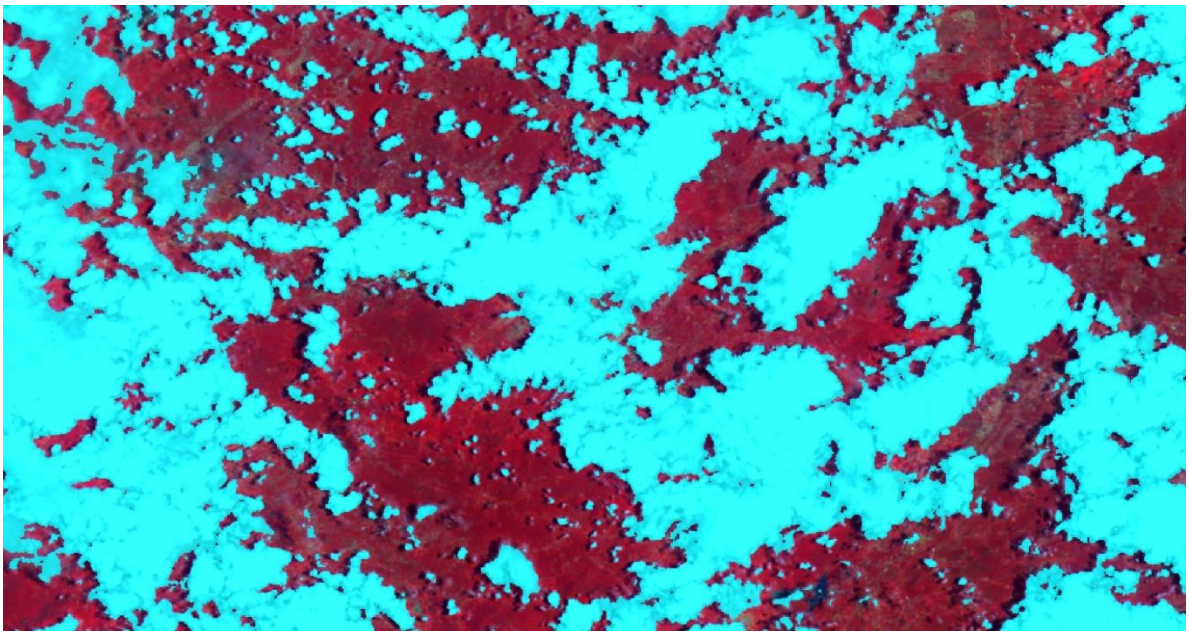


!SM_FLAGS_GOOD_BLUE

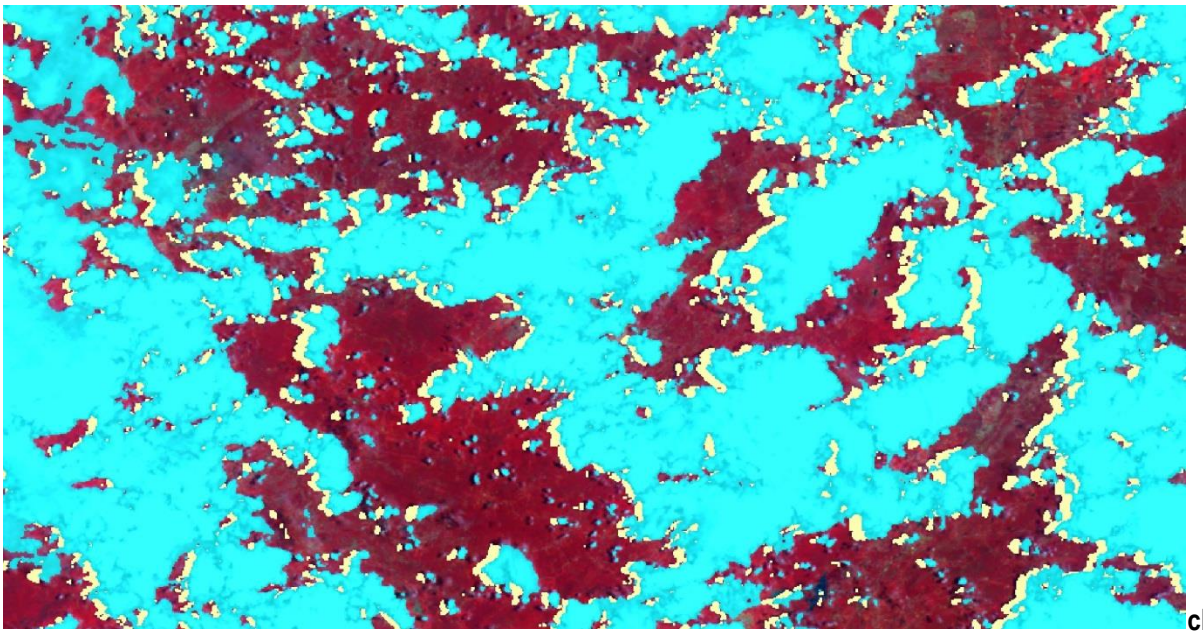
16. PROBAV_S1_TOA_X13Y07_20140321_100M_V101 (North Brazil in the Southeast of Amazon Delta)



RGB



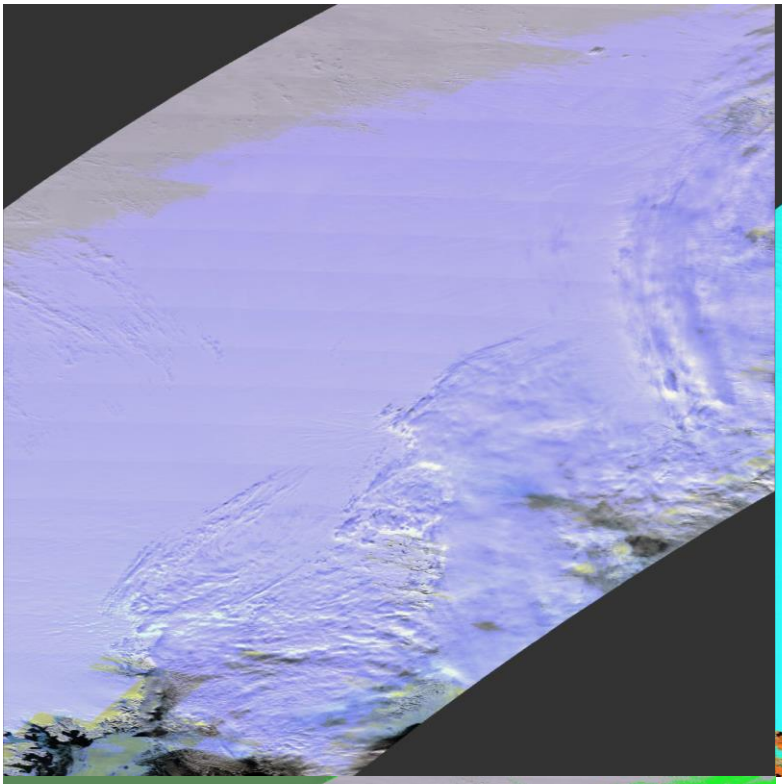
cloud mask

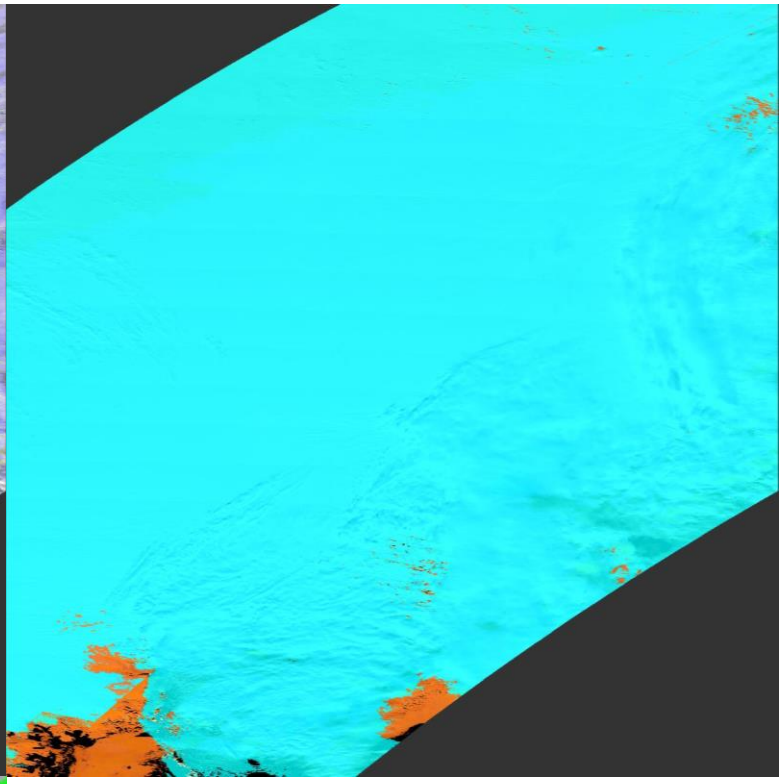


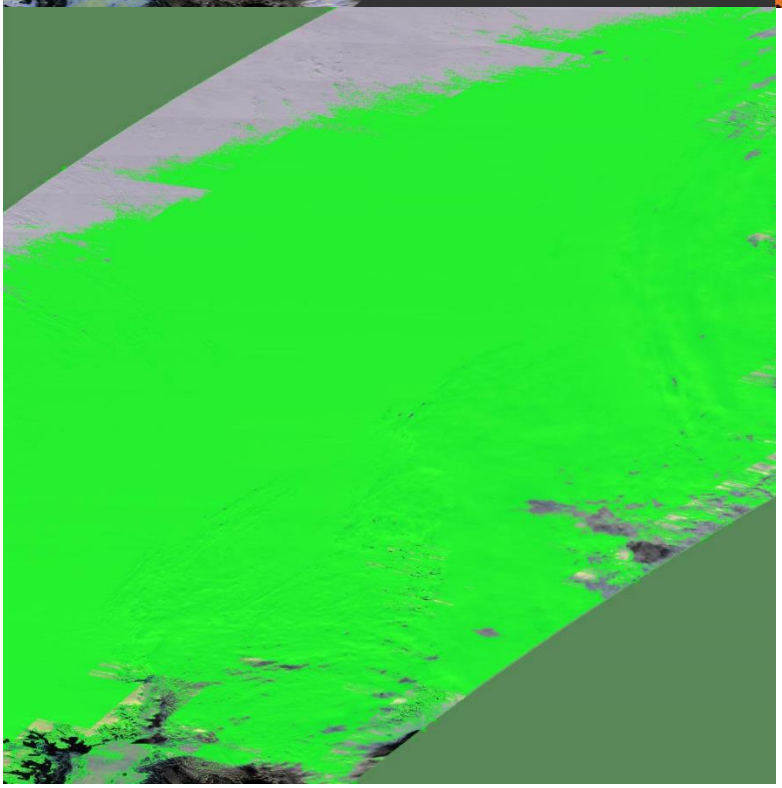
clouds & shadows

Well done.

17. PROBAV_S1_TOA_X14Y00_20140321_100M_V101 (Kommuneqarfik Sermersooq)



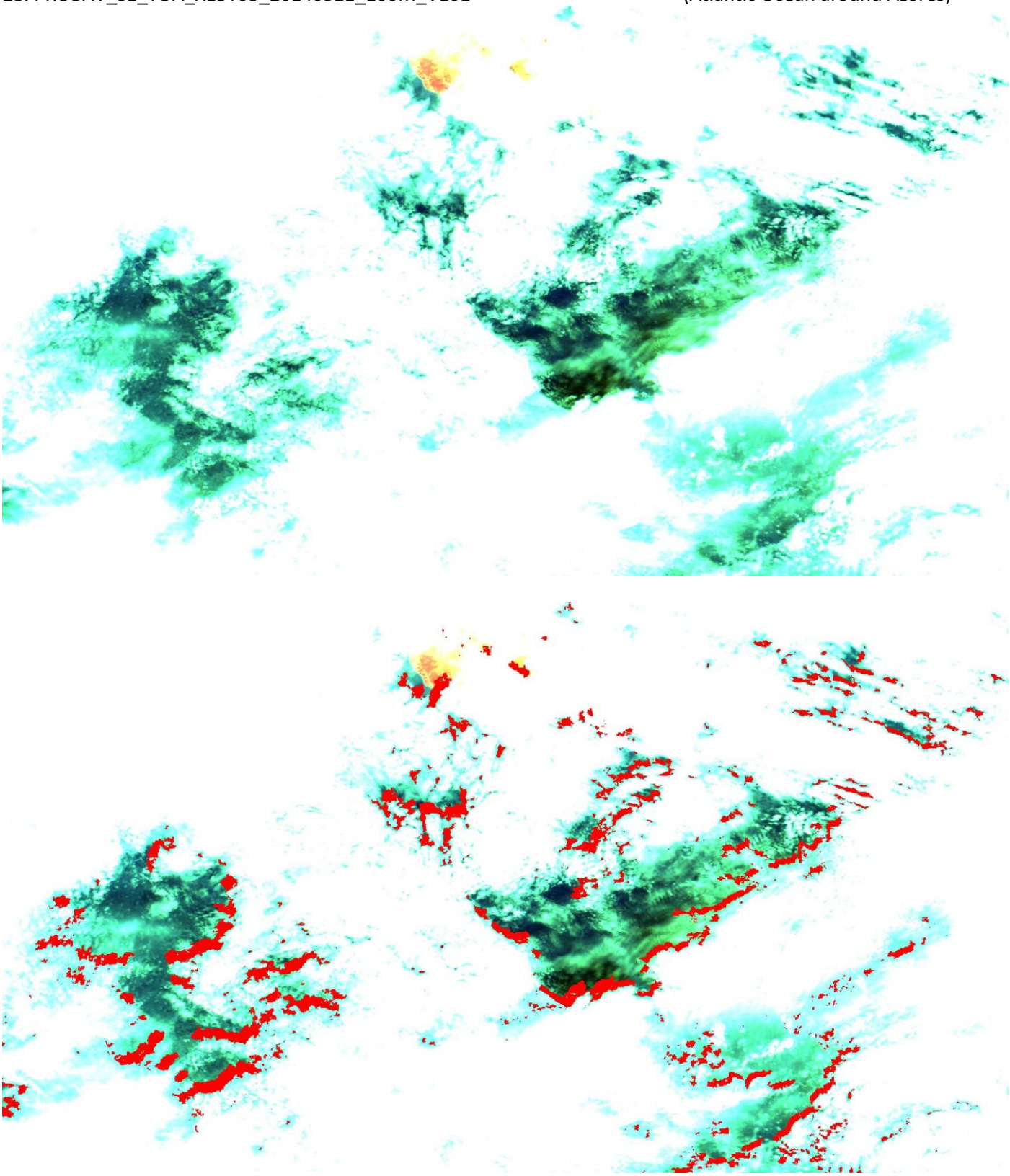




The continental clear sky Greenland ice was incorrectly identified as cloudy.

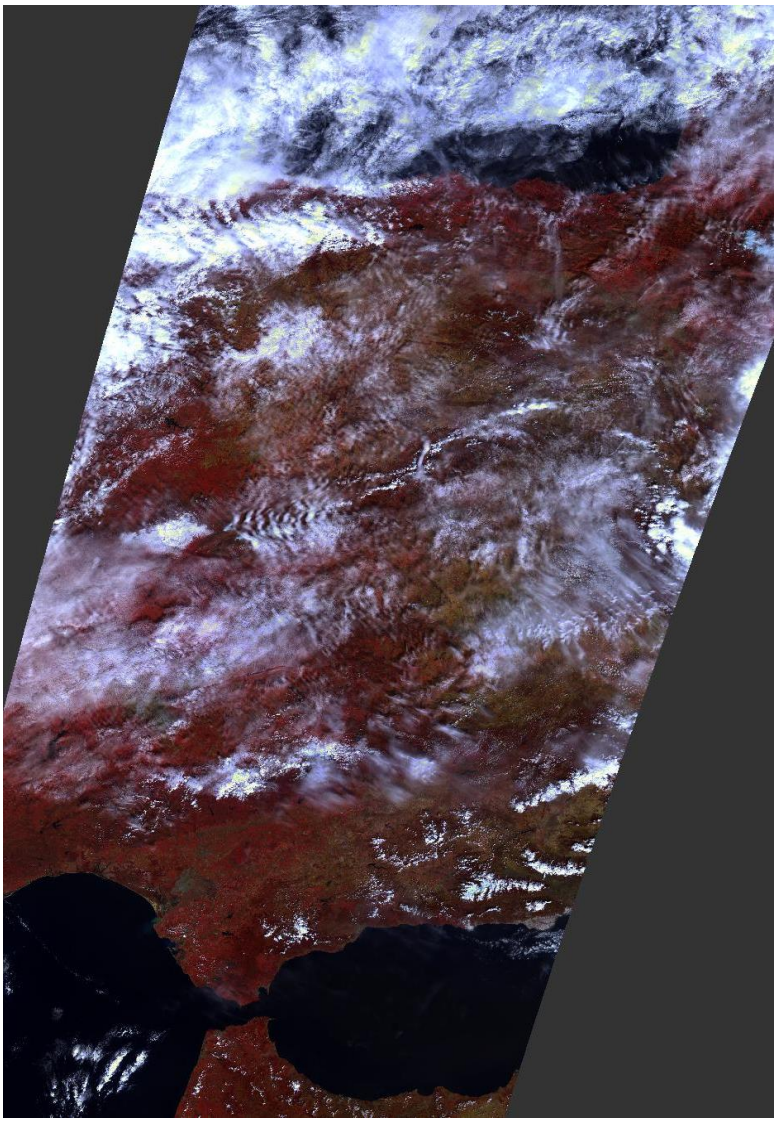
🡐 Maybe that's because of the mask "!SM_FLAGS_GOOD_BLUE".

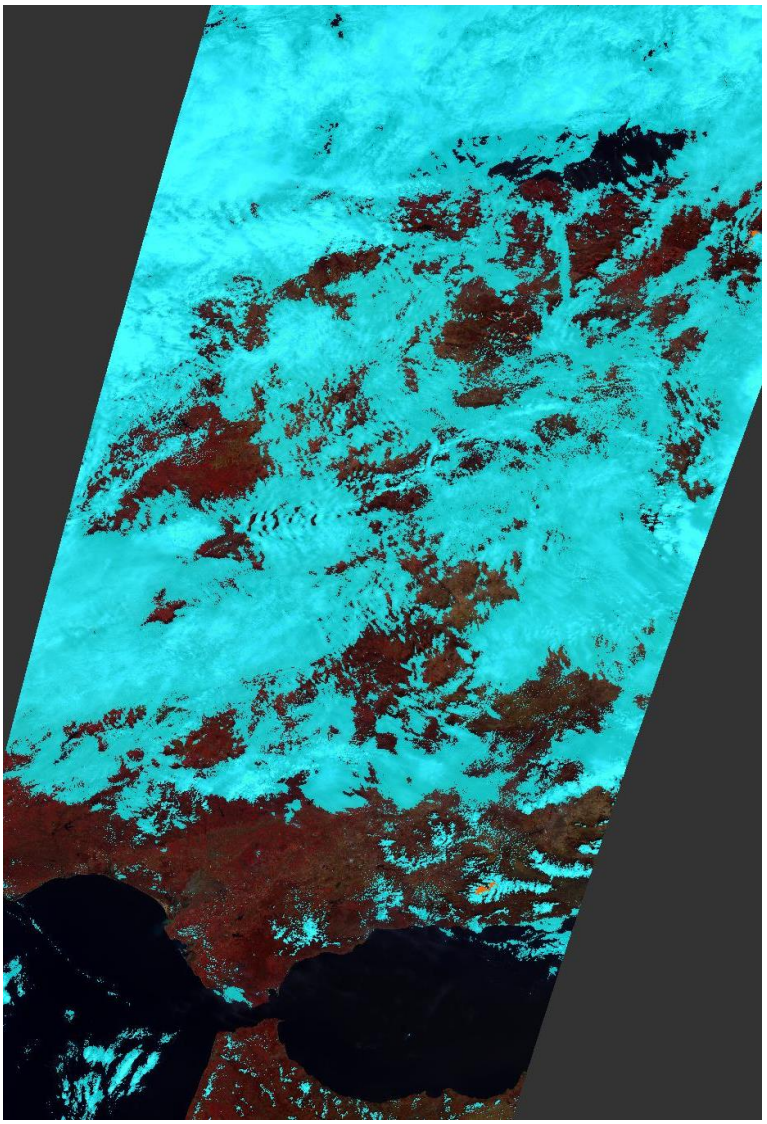
18. PROBAV_S1_TOA_X15Y03_20140321_100M_V101 (Atlantic Ocean around Azores)



Cloud shadow mask was displayed over the thin clouds. Usually the method does not show the shadows over the clouds.

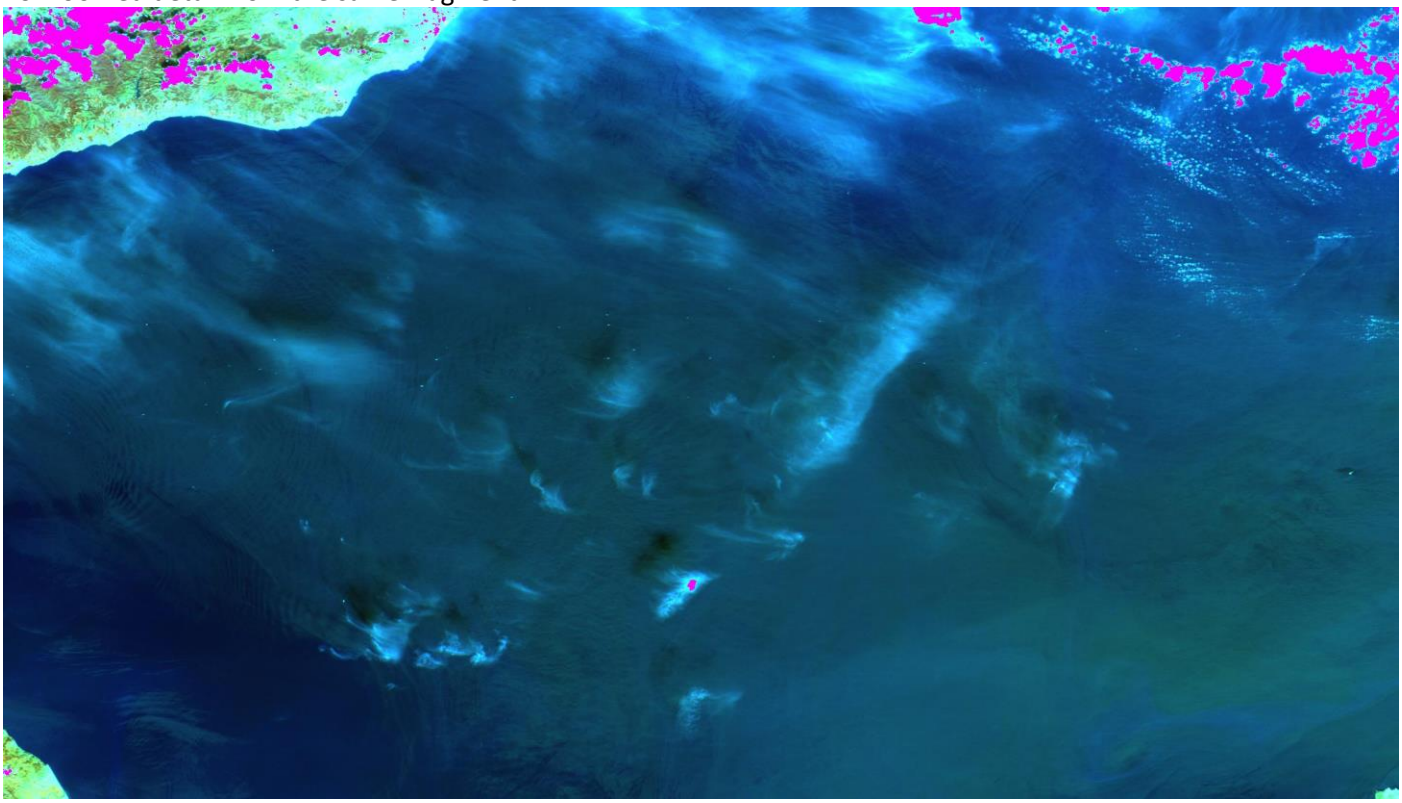
19. PROBAV_S1_TOA_X17Y03_20140321_100M_V101 (Spain)





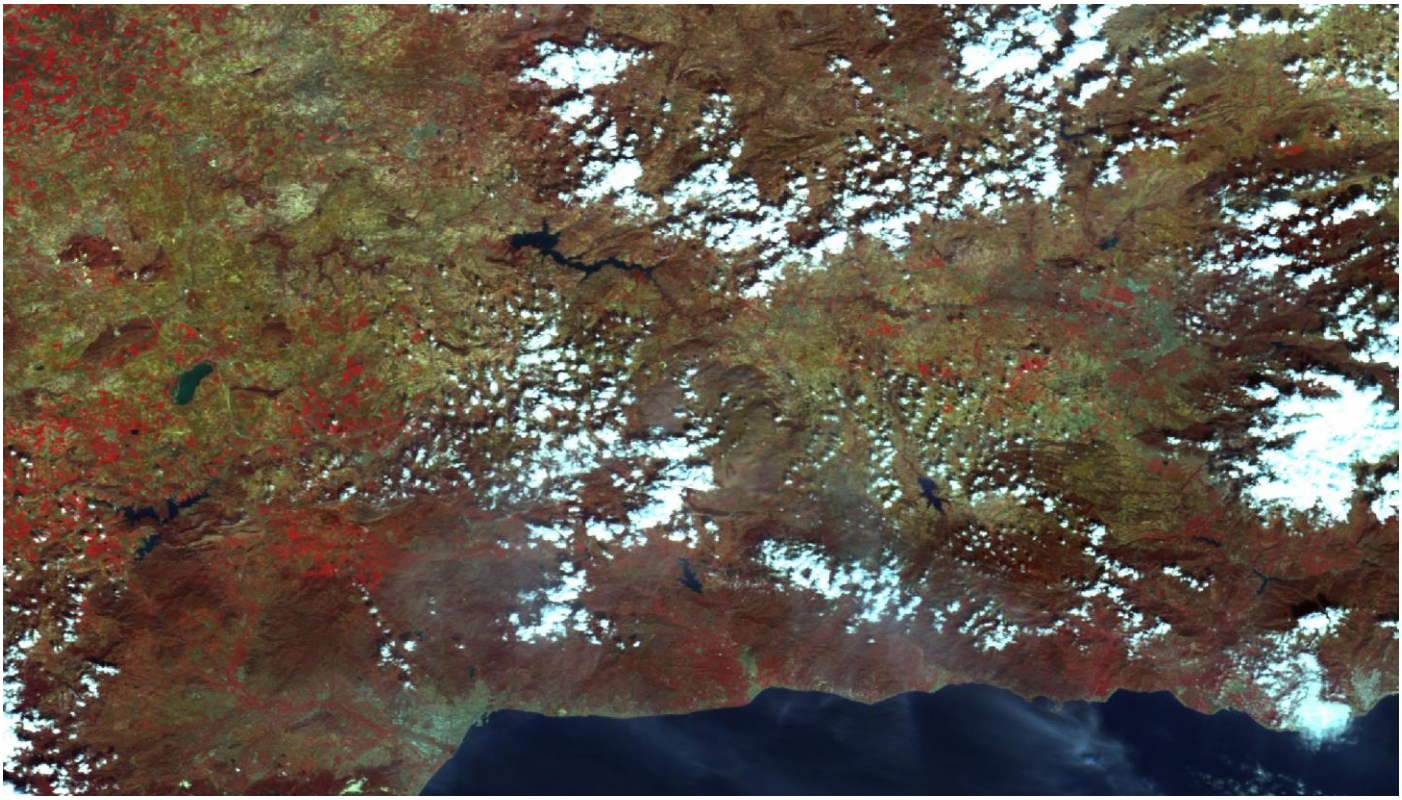
An overall good cloud mask.

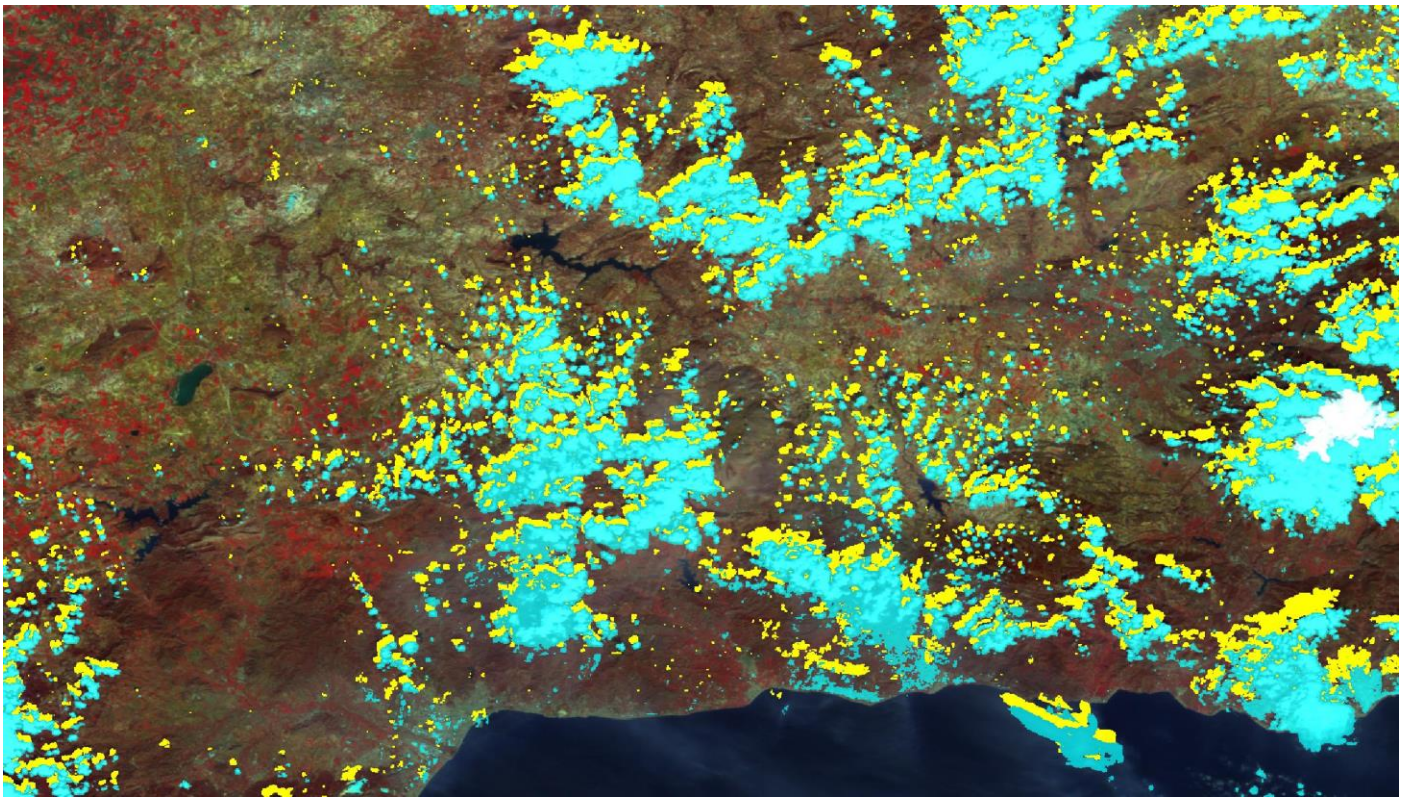
20. Zoomed detail from the same fragment.



Thin clouds over Alboran Sea was not well recognized (cloud mask - **rose**).

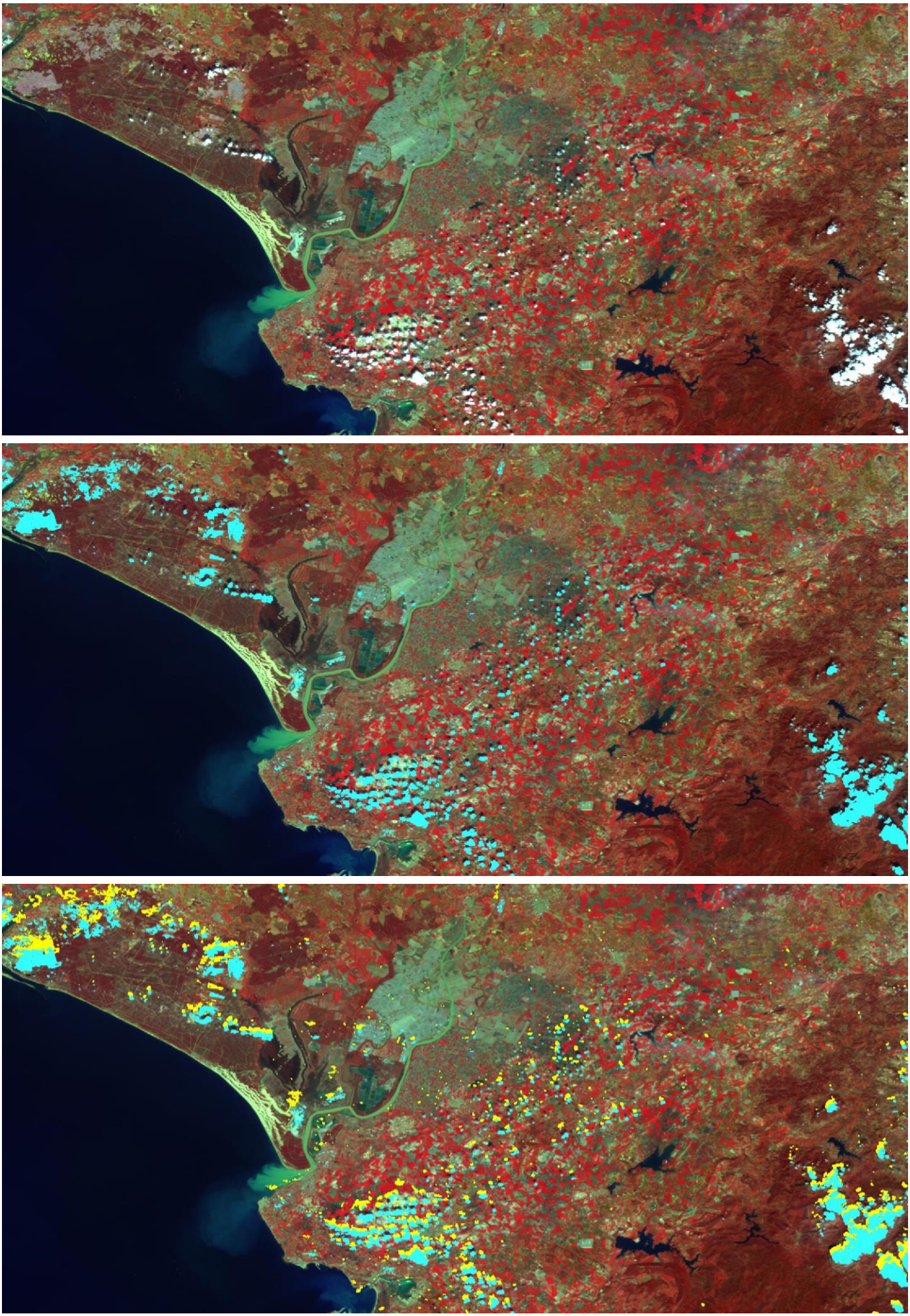
21. Zoomed detail from the same fragment.



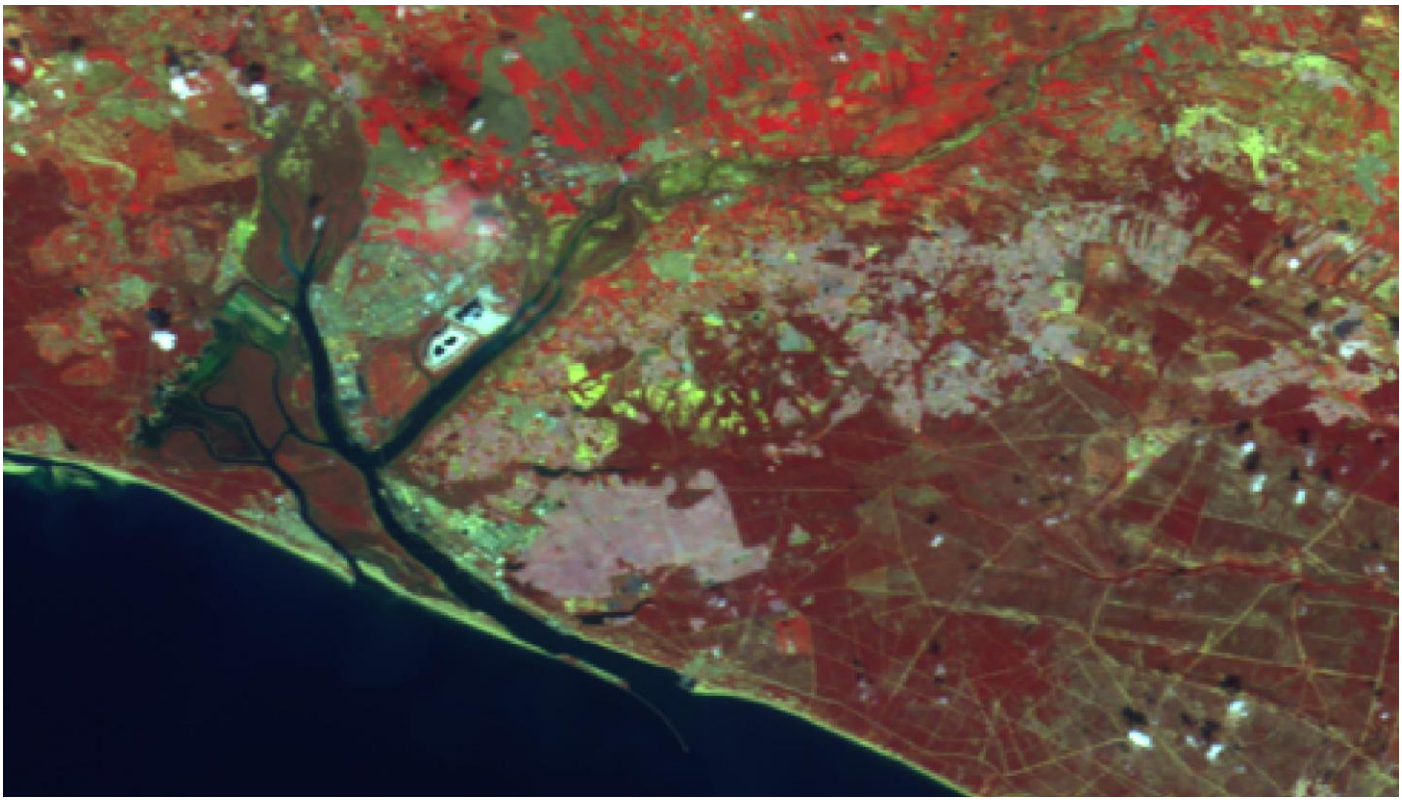


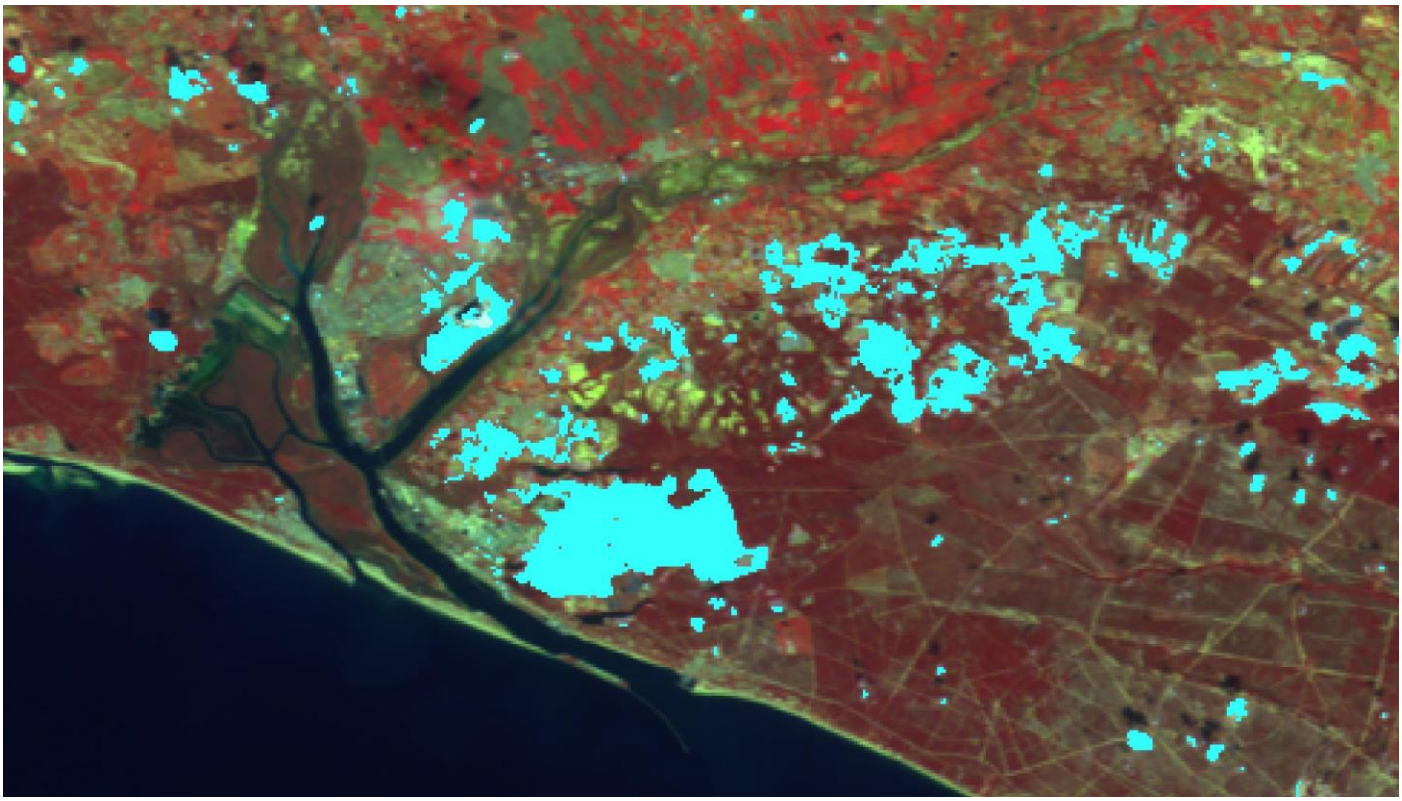
Well done cloud/shadow mask. Some very thin semi-transparent clouds were not recognized as such.

22. Zoomed detail from the same fragment.



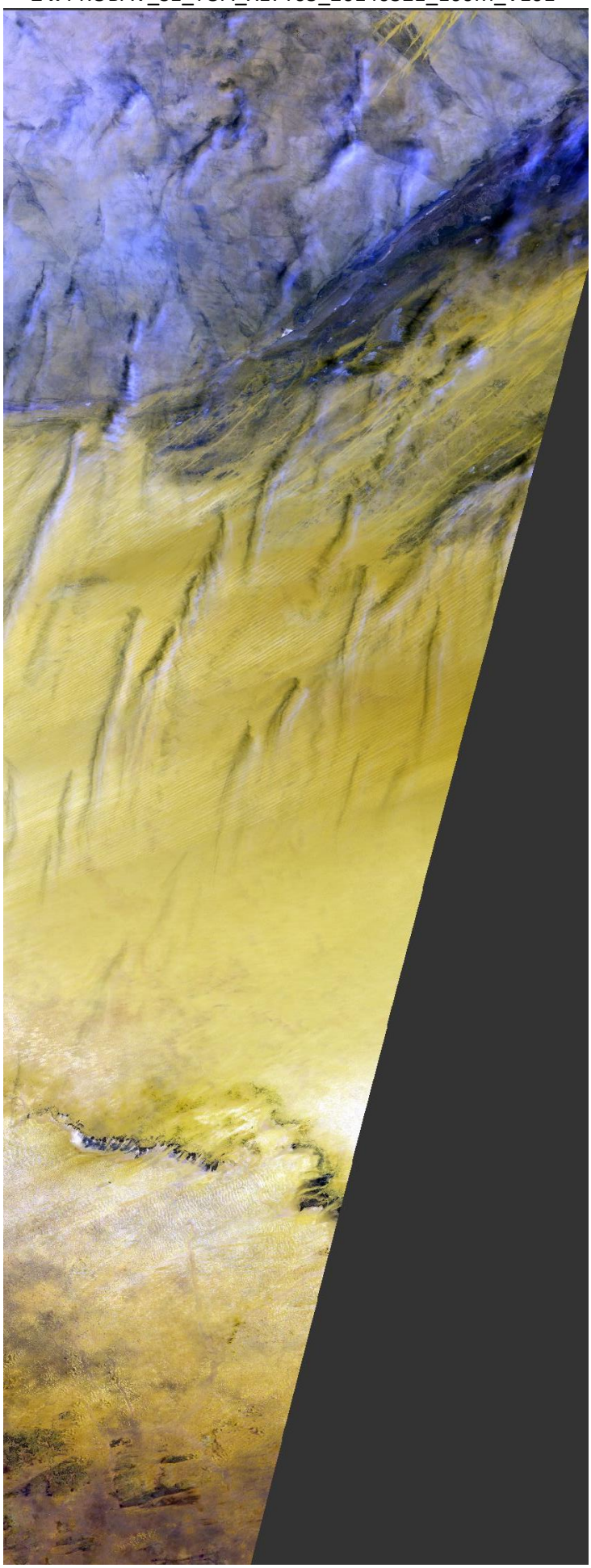
23. Zoomed detail from the same fragment.

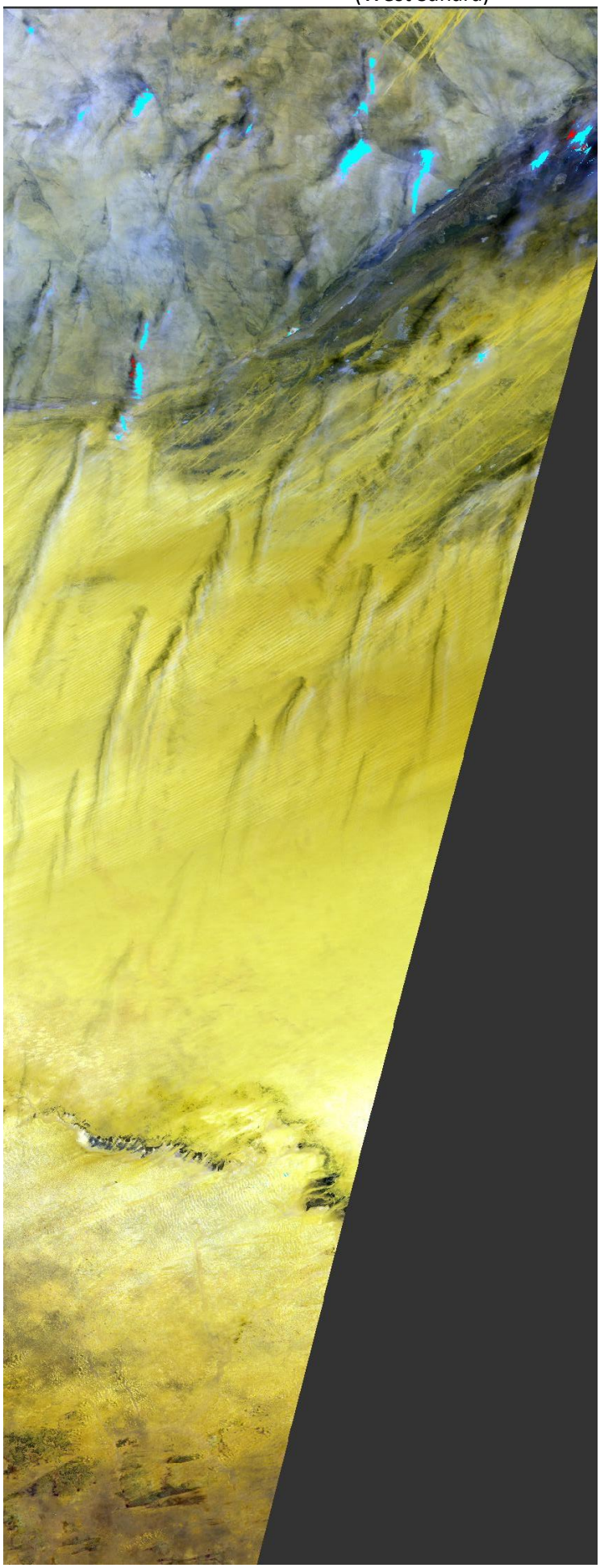




Description to №№ 22, 23.
An old problem. Some urban buildings and artificial structures can be confused with clouds by the cloud detection method.
In the case of the displayed image, the shadows without clouds can be even seen (№22). But the water reservoirs and roofs of greenhouses of impressive sizes are also mistaken for clouds (№23). As a result, they should cast shadows, which are indicated with the appropriate mask (№22). These all is a method error.

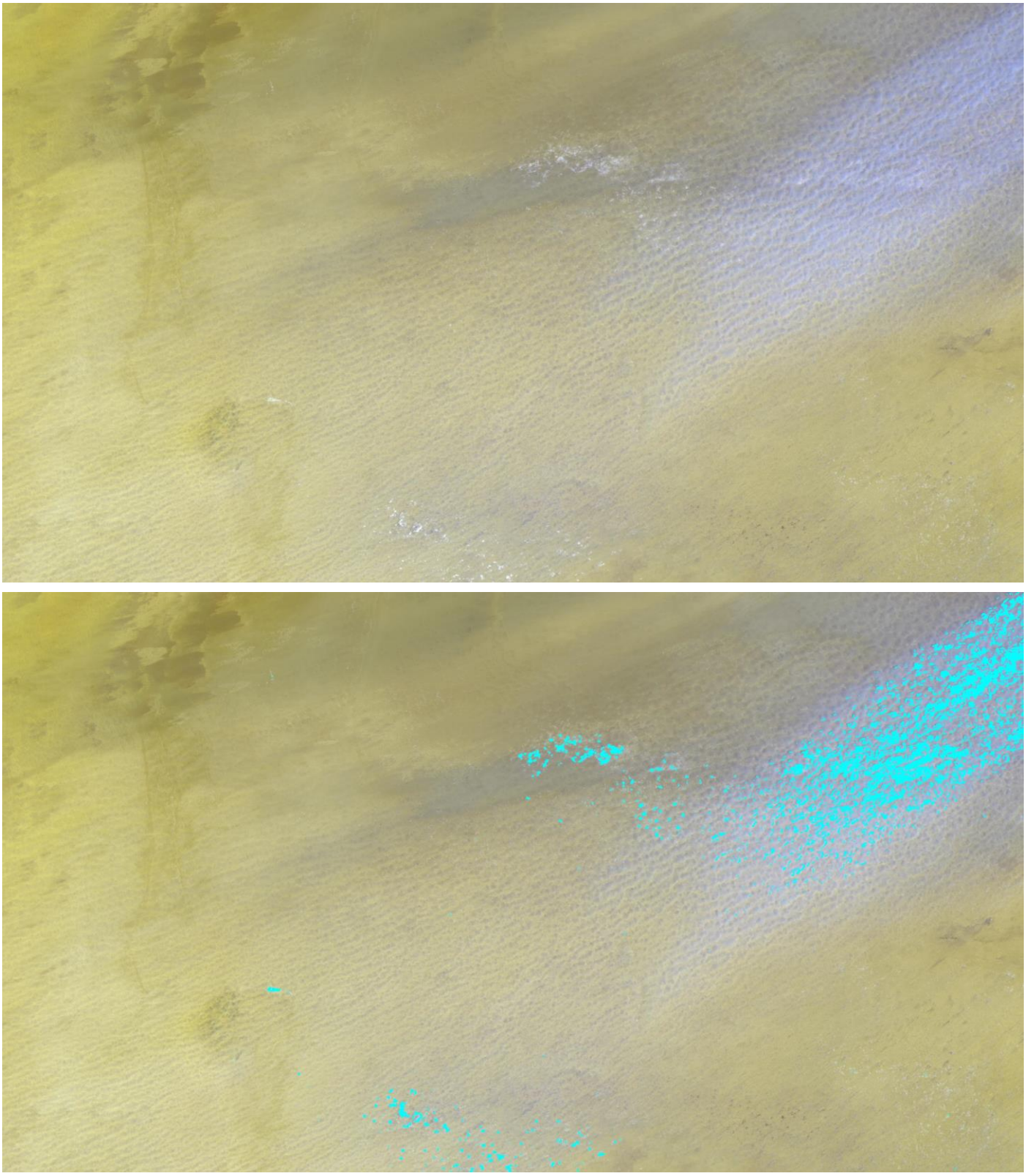
24. PROBAV_S1_TOA_X17Y05_20140321_100M_V101 (West Sahara)





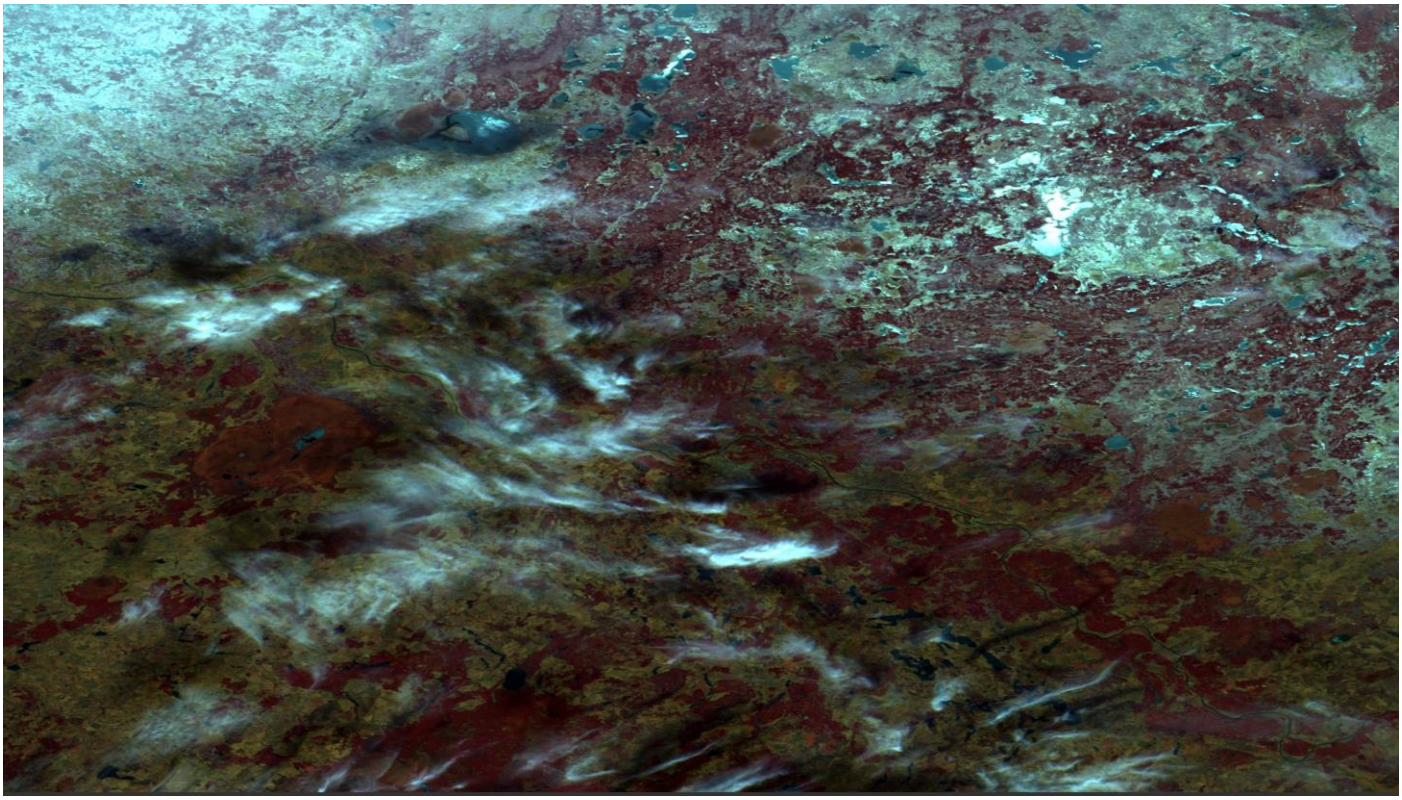
Quite easily recognizable clouds over the desert (Sahara) were not identified by the method (similar picture as with the 1km data).

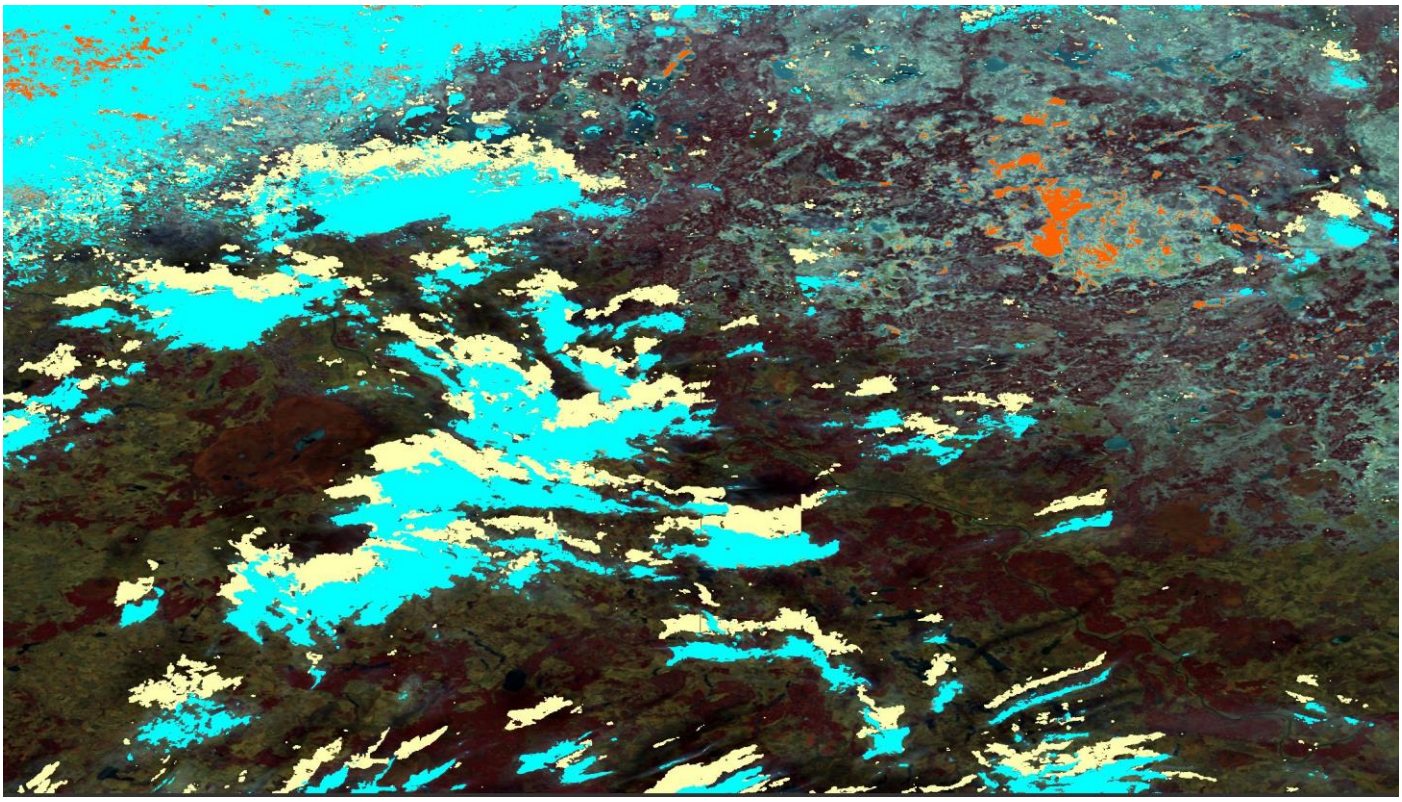
25. Zoomed detail from the same fragment.



Part of fairly thin cumulus clouds over the desert was not recognized.

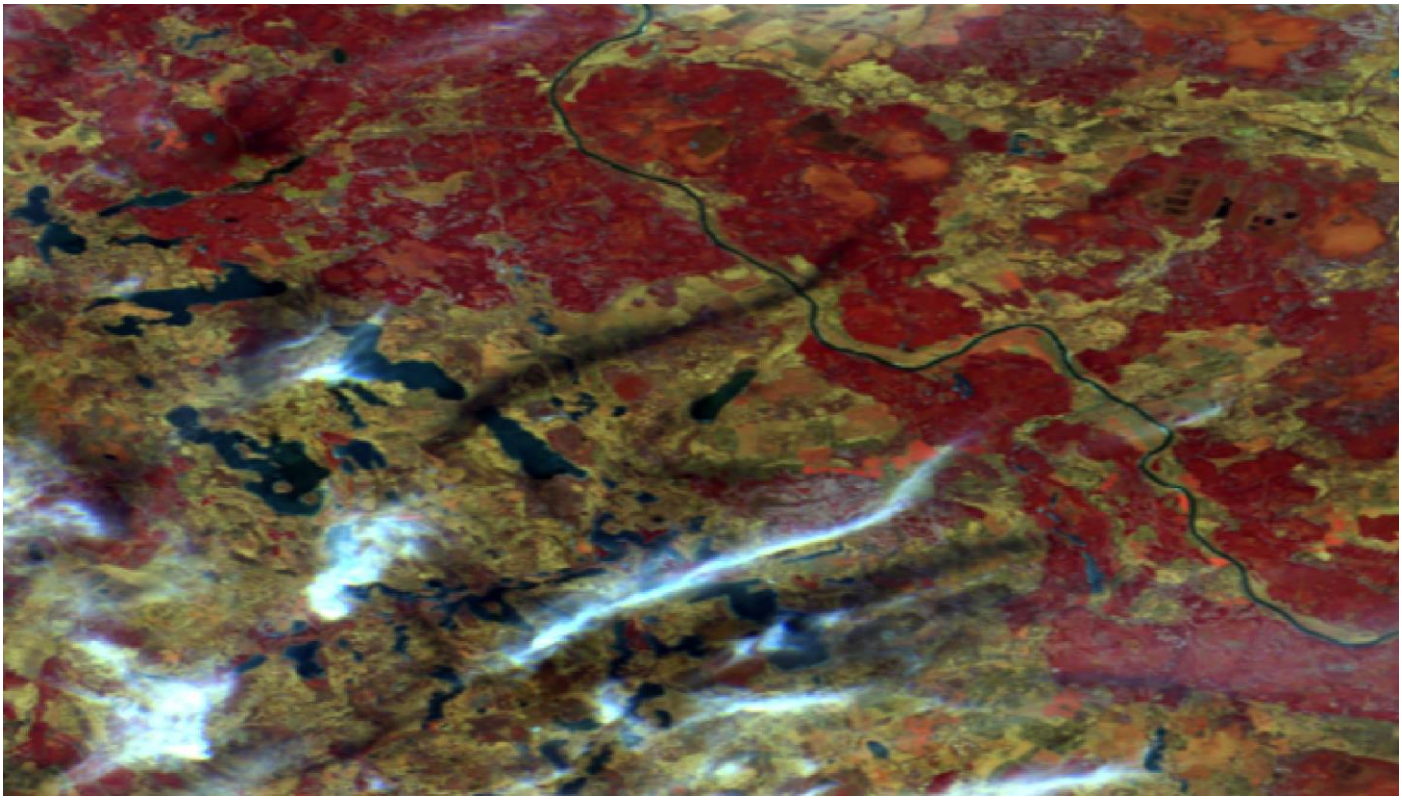
26. PROBAV_S1_TOA_X20Y01_20140321_100M_V101 (Belorussia)

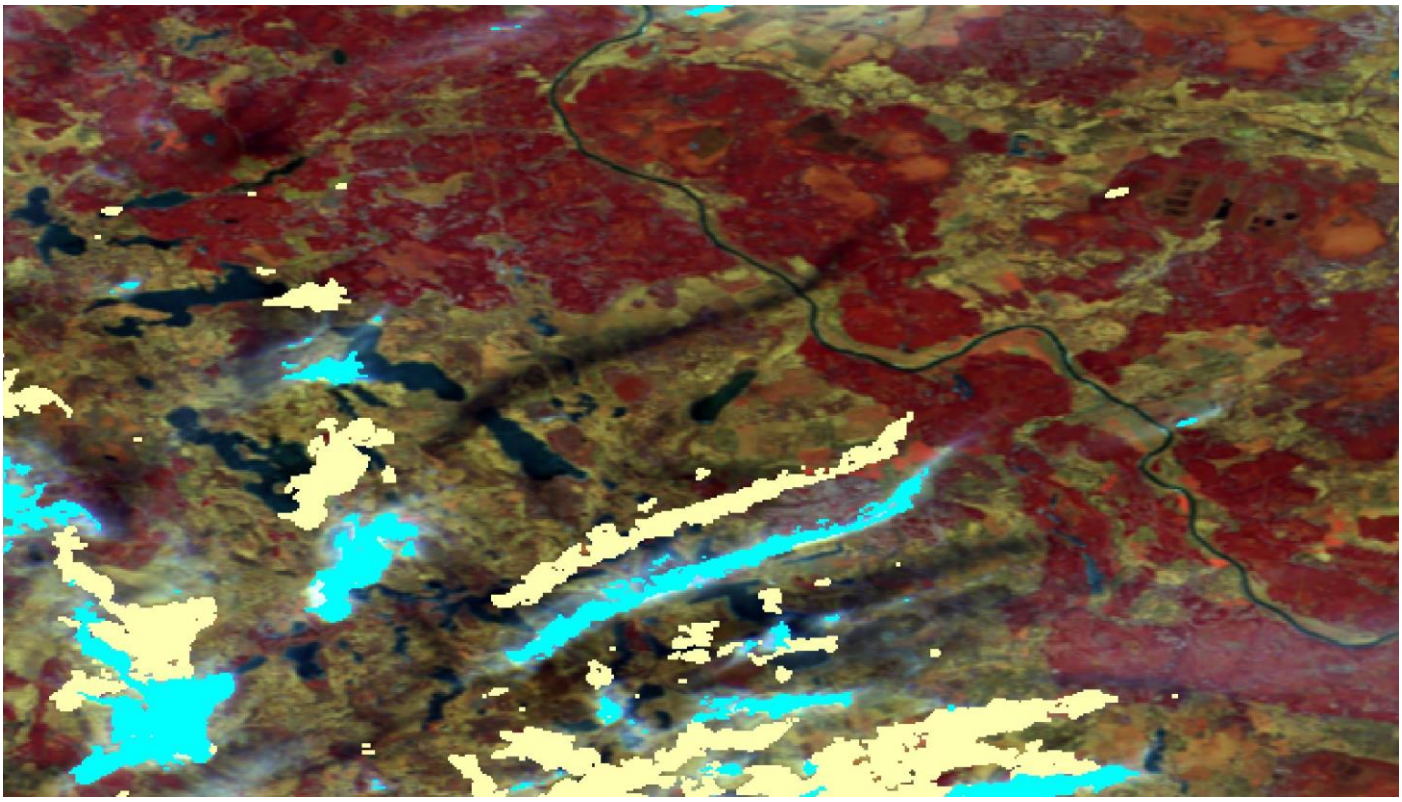




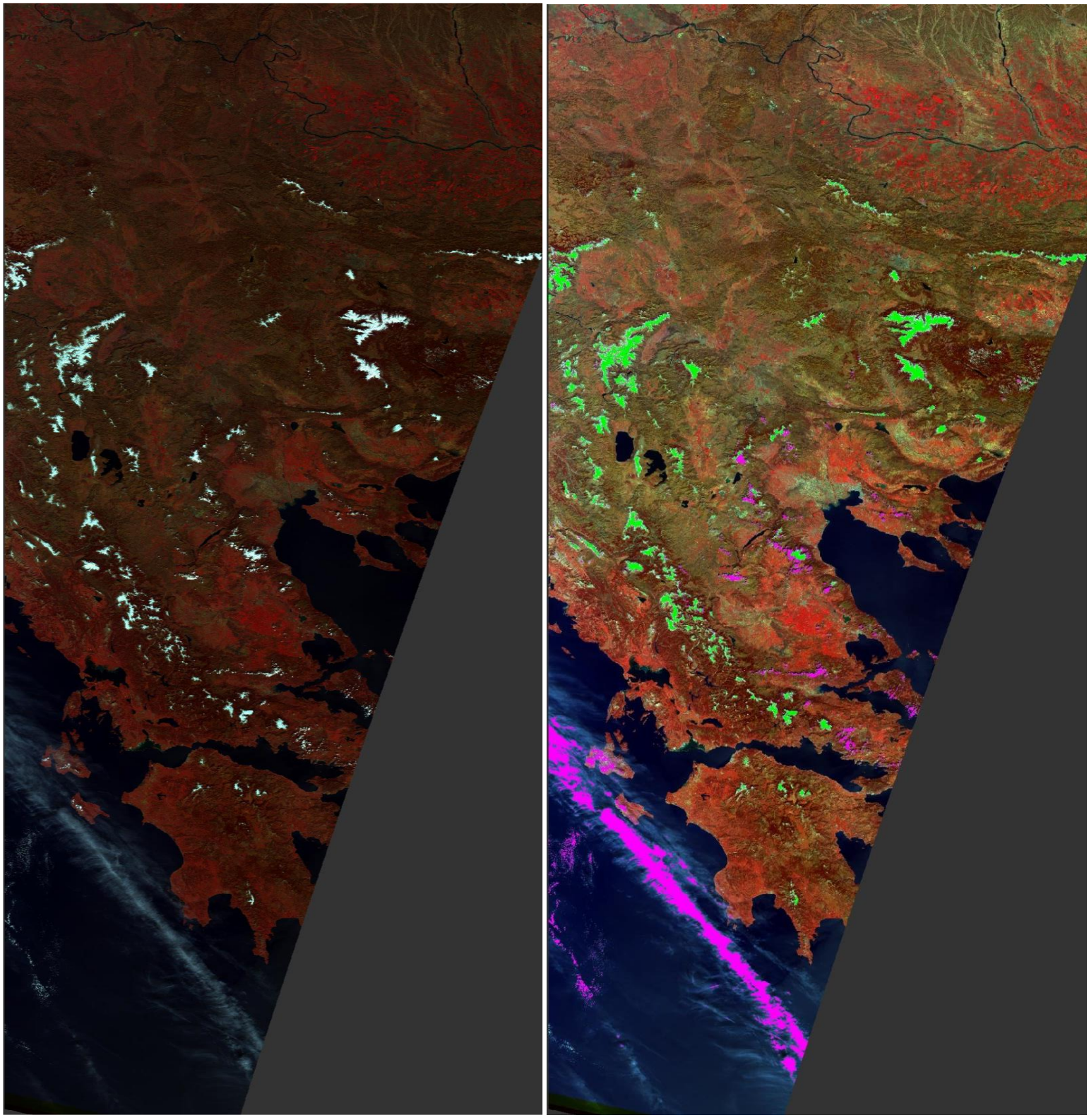
Completely wrongly produced cloud shadow mask (see also №27). Obviously, cloud heights were not correctly assessed: they were considered too low. In reality, the clouds are estimated to be up to 3 times higher.
The snow-covered and partially snow-covered regions (№26 above; left and less - right) have been incorrectly identified as cloudy.

27. Zoomed detail from the same fragment.



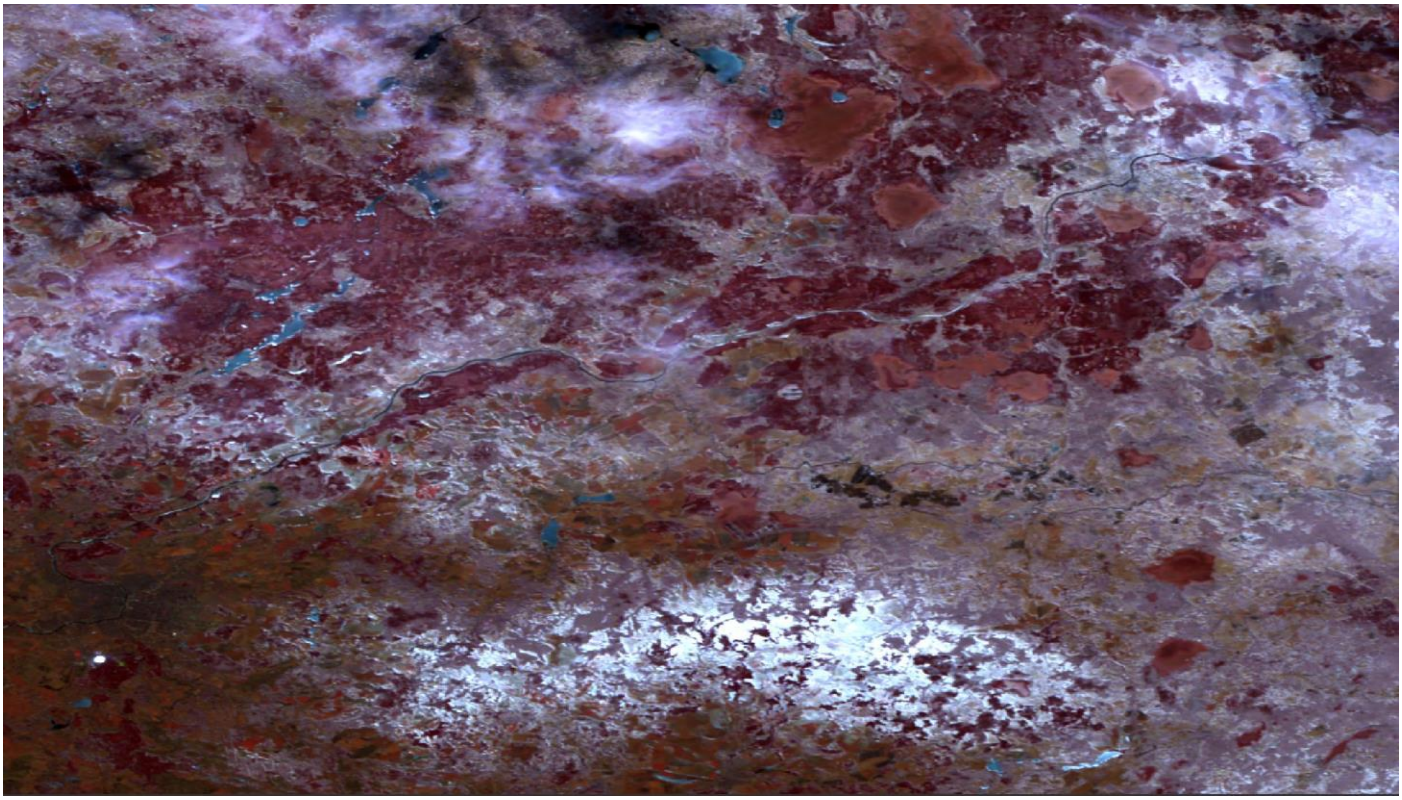


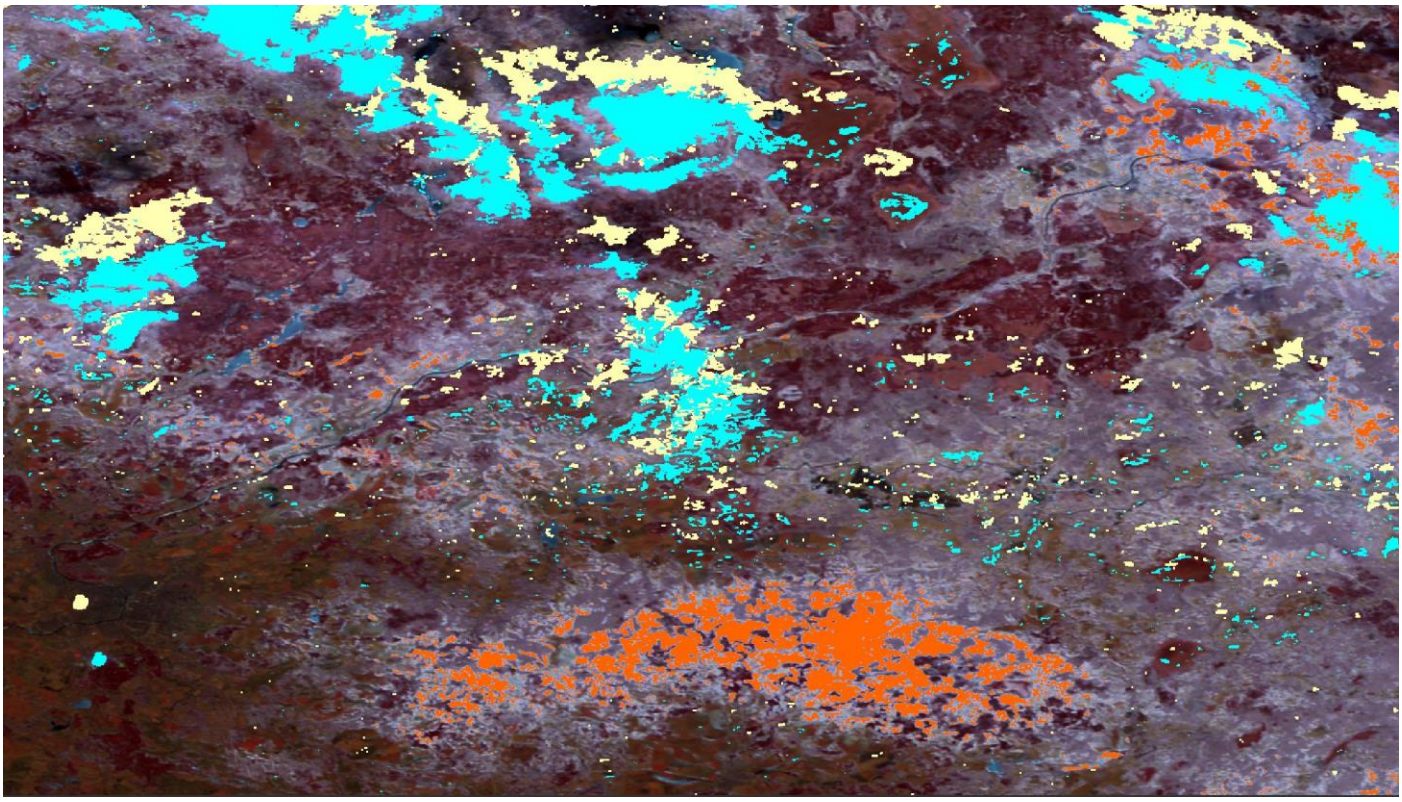
28. PROBAV_S1_TOA_X20Y03_20140321_100M_V101 (Greece)



That's rather good masking. Some thin, semi-transparent clouds over the sea remained undetected.

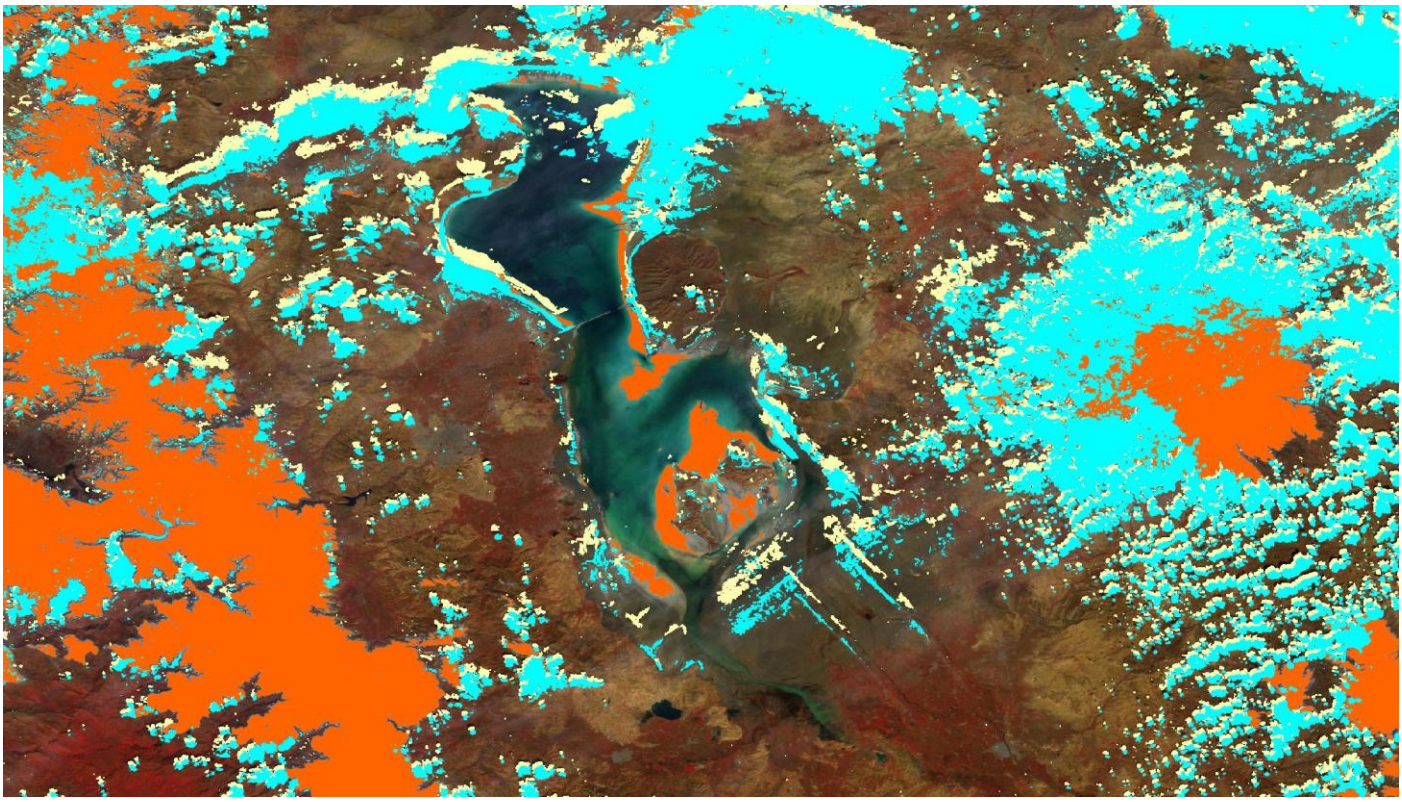
29. PROBAV_S1_TOA_X21Y01_20140321_100M_V101 (Northwest of Russia)





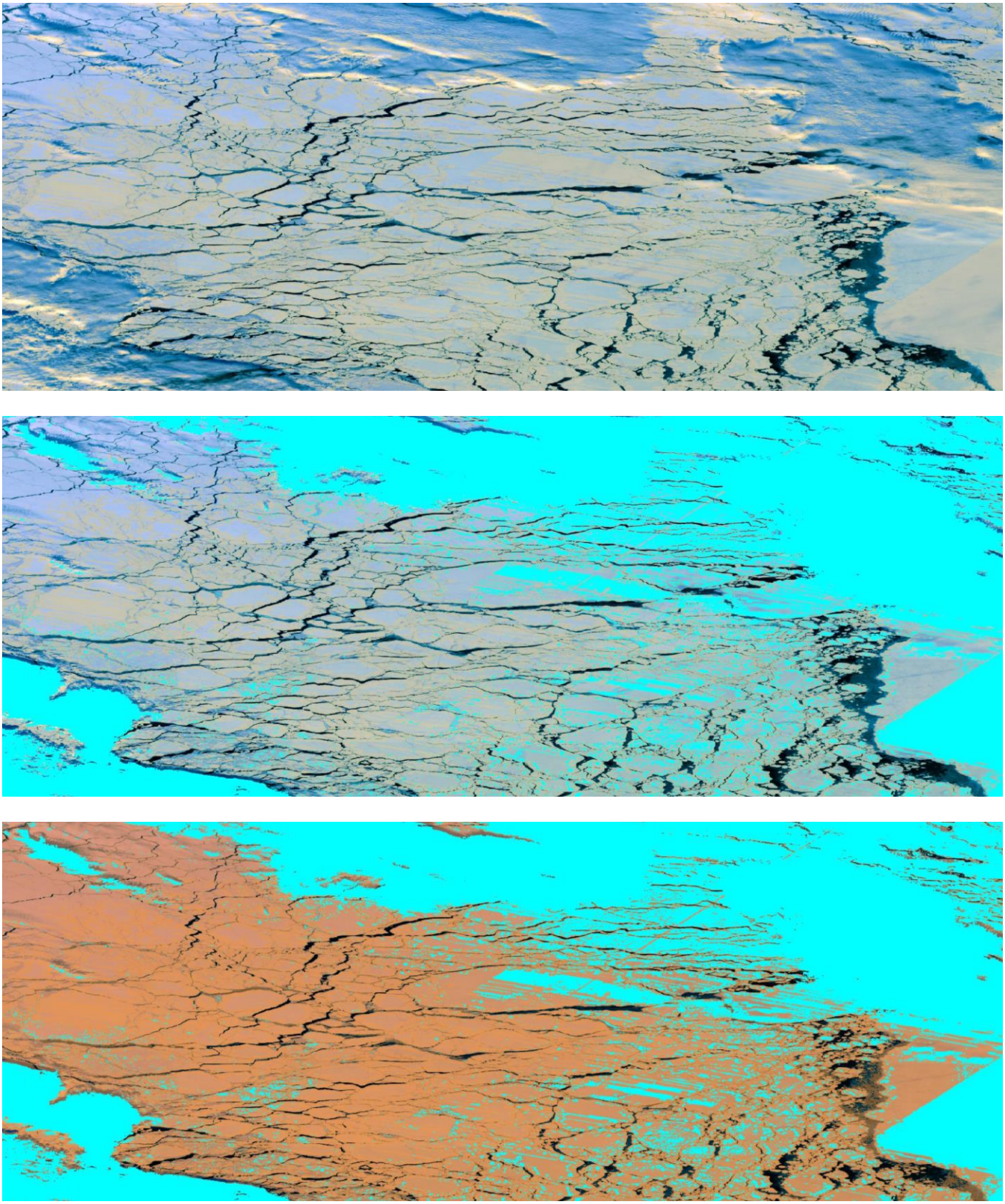
Partially snow-covered pixels were incorrectly identified as cloudy. Several partially snow-covered pixels are not masked at all. This happens with many dates, where there are partially snow-covered (either way defined) regions. It is either a method error or such areas are intentionally intended for non-masking.

30. PROBAV_S1_TOA_X22Y03_20140321_100M_V101 (Northwest of Iran, Lake Urmia)



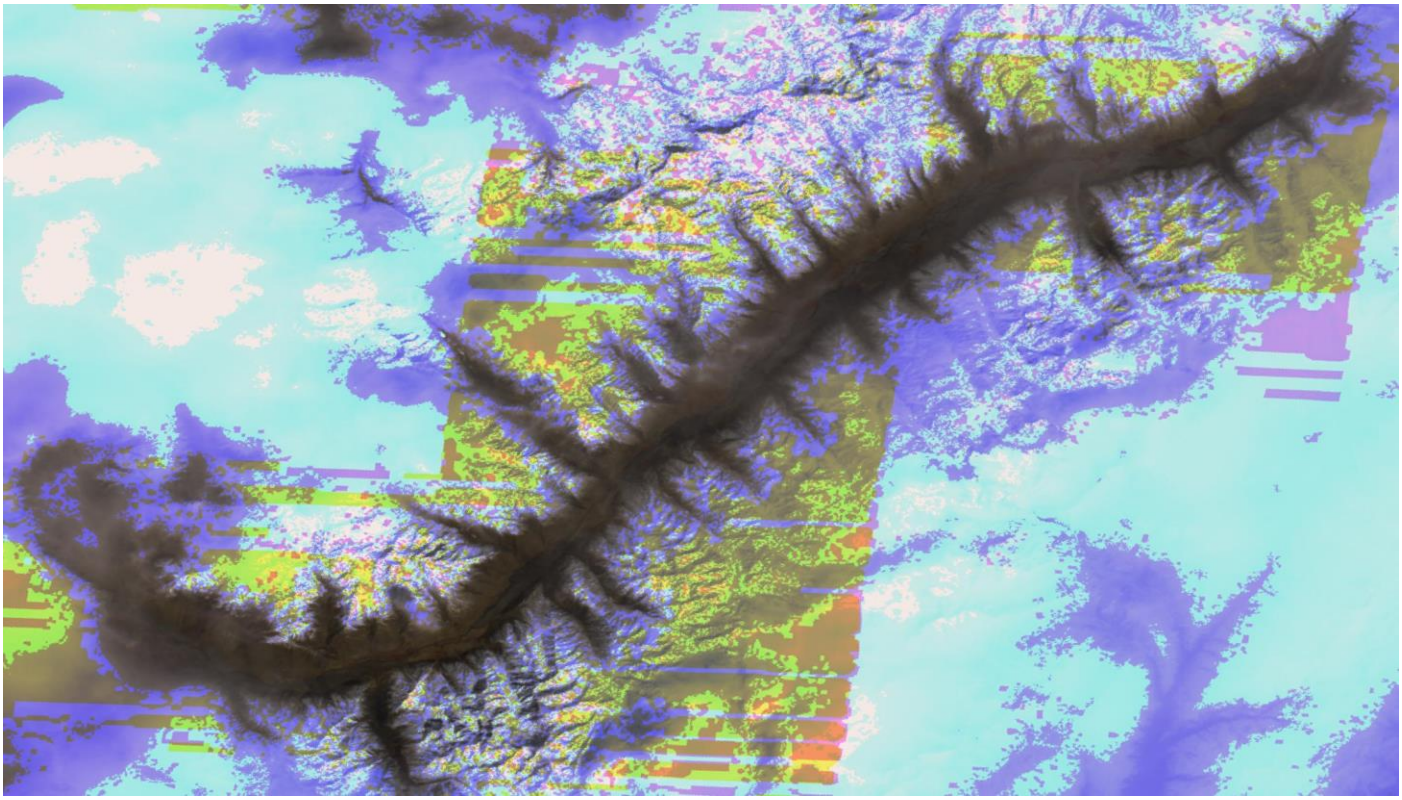
Some cloud-free pixels around the lake are incorrectly masked as cloudy. That is probably sand.
Just more pixels of sandy coasts and sand banks pixels (transparent water over the sandy shoals) are masked as ice / snow. This is a fairly typical case (wet sand masked as ice).

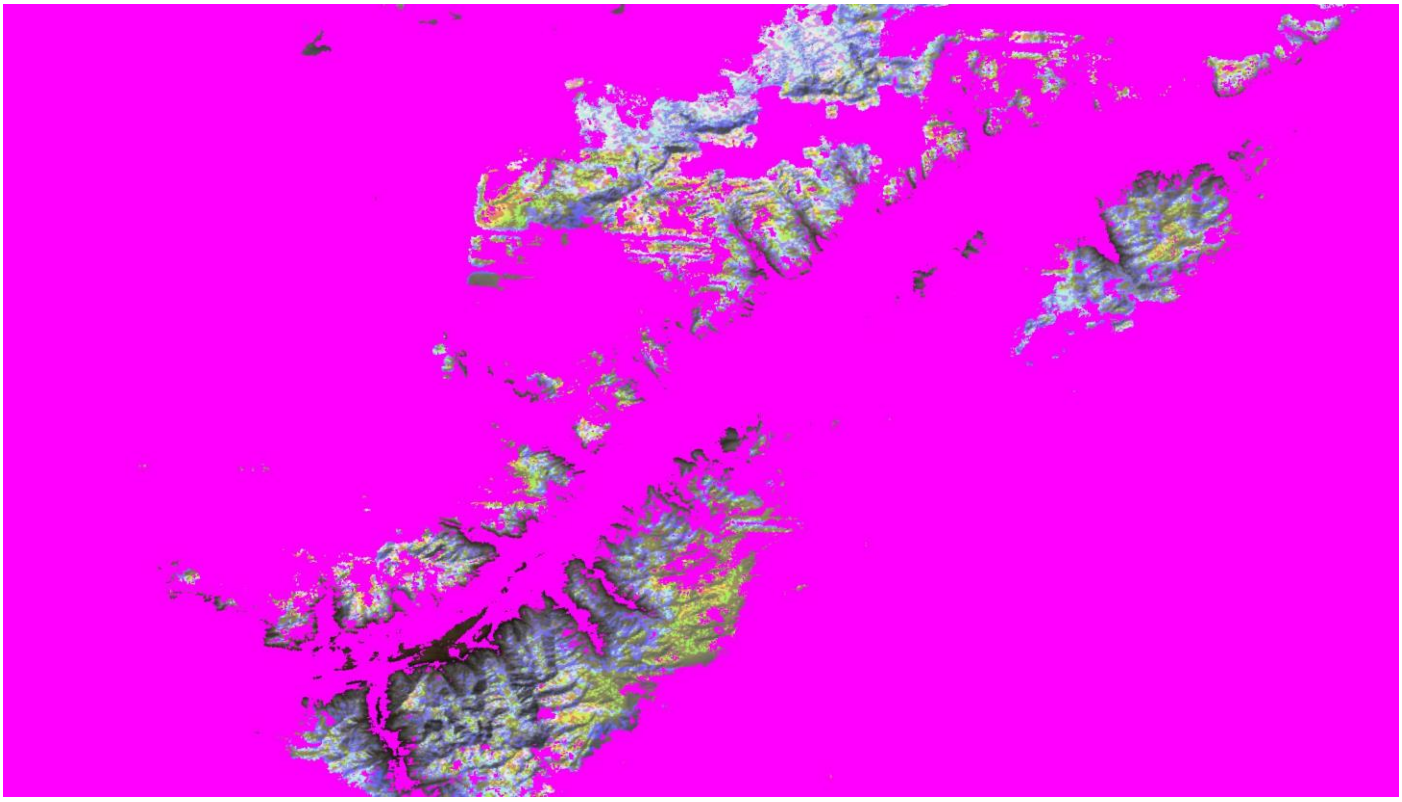
31. PROBAV_S1_TOA_X24Y00_20140321_100M_V101 (Kara Sea)



From top to bottom: RGB, cloud mask, cloud & ice masks.
It is better solved than 6, 13, but the "**!**_SM_FLAGS_GOOD_BLUE" mask "leaves its traces" and affects the cloud mask negatively.

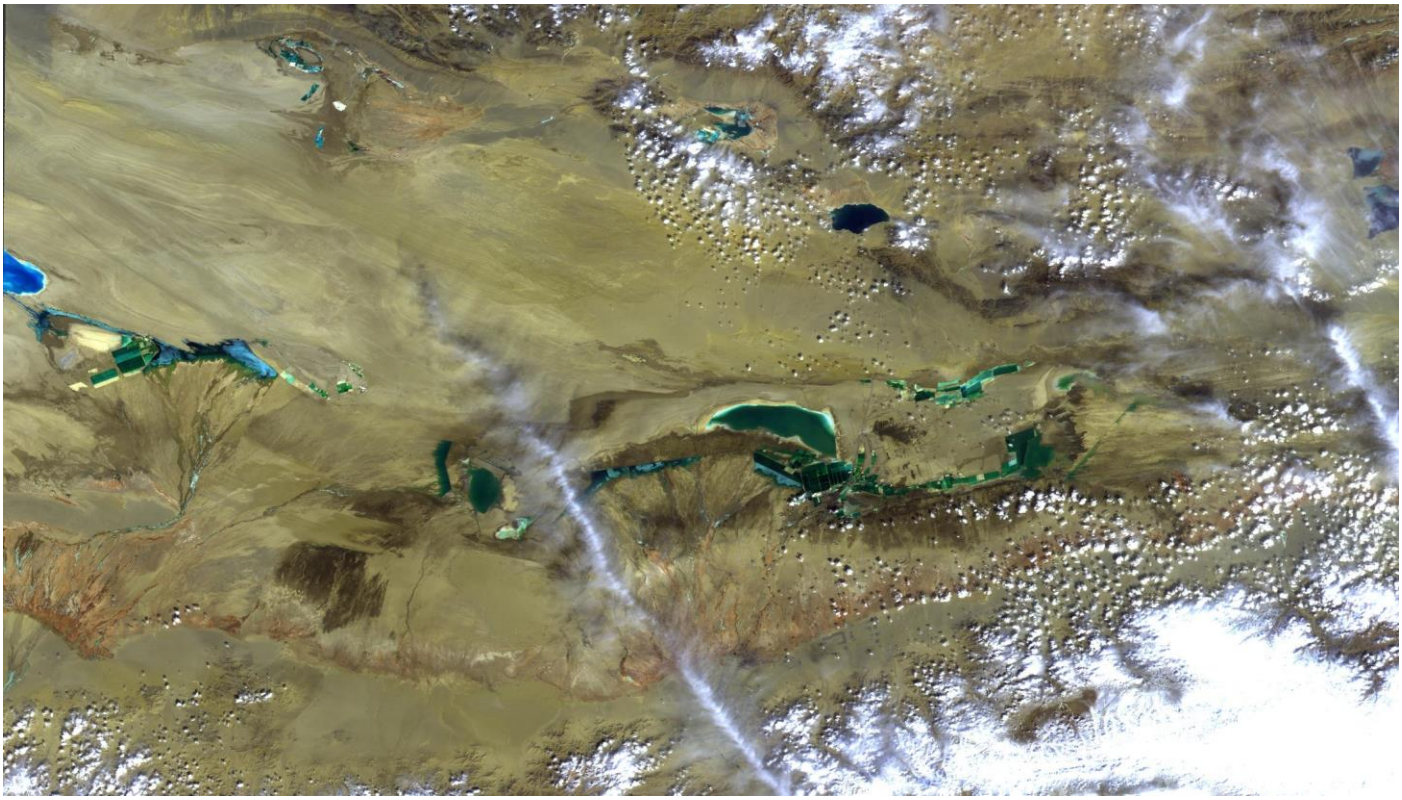
32. PROBAV_S1_TOA_X25Y03_20140321_100M_V101 (Tajikistan, Badahshan Mountains)

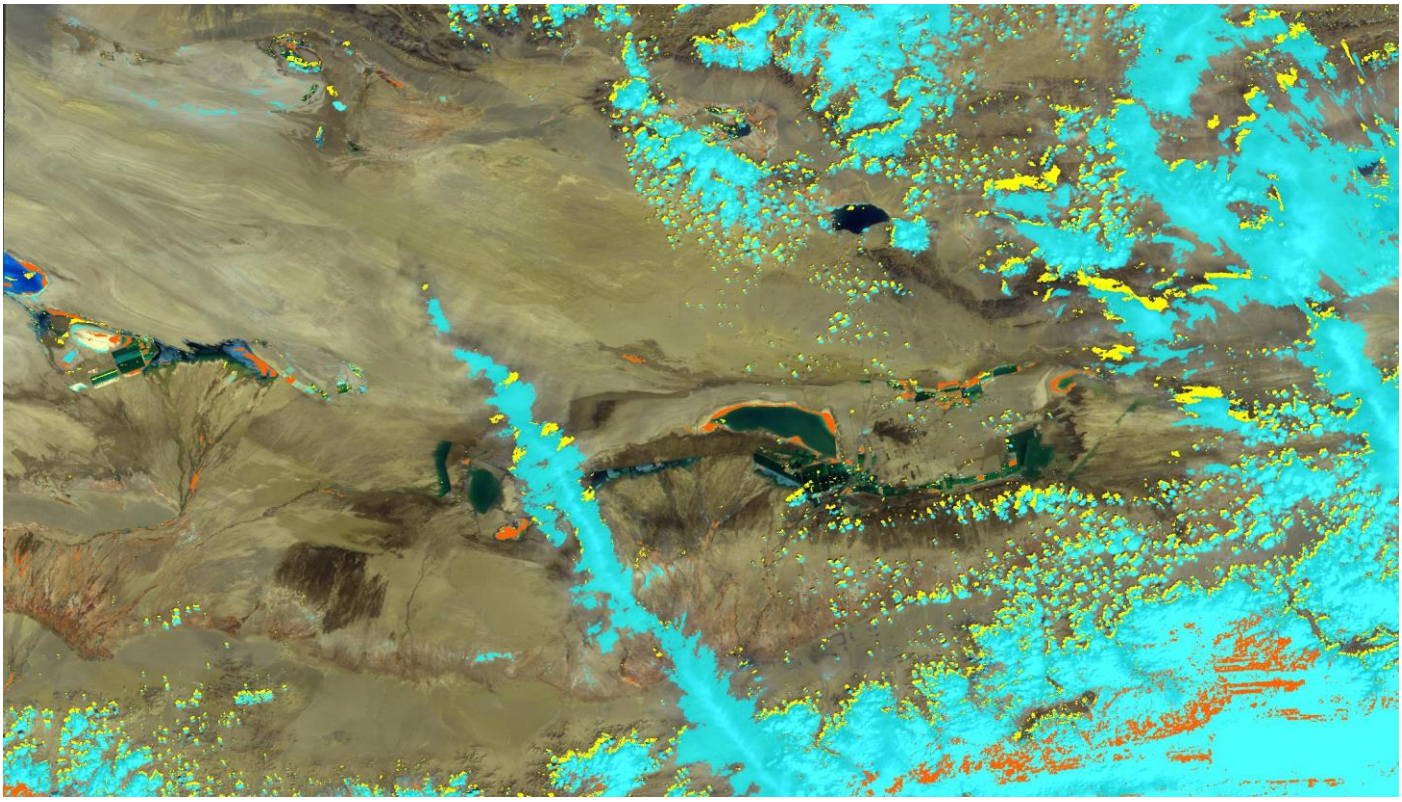




In the picture above there are no cloud or snow etc. masks. Only allegedly "damaged" pixels are indicated. A cloud-free (apparently also snow-free) mountain valley can be seen, which is the only object in this region that has no *damaged* (whatever that means - see corresponding "SM GOOD" flags) pixels in any channel. When masking, however, it is also covered with an ice/snow mask (rose). I have my doubts.

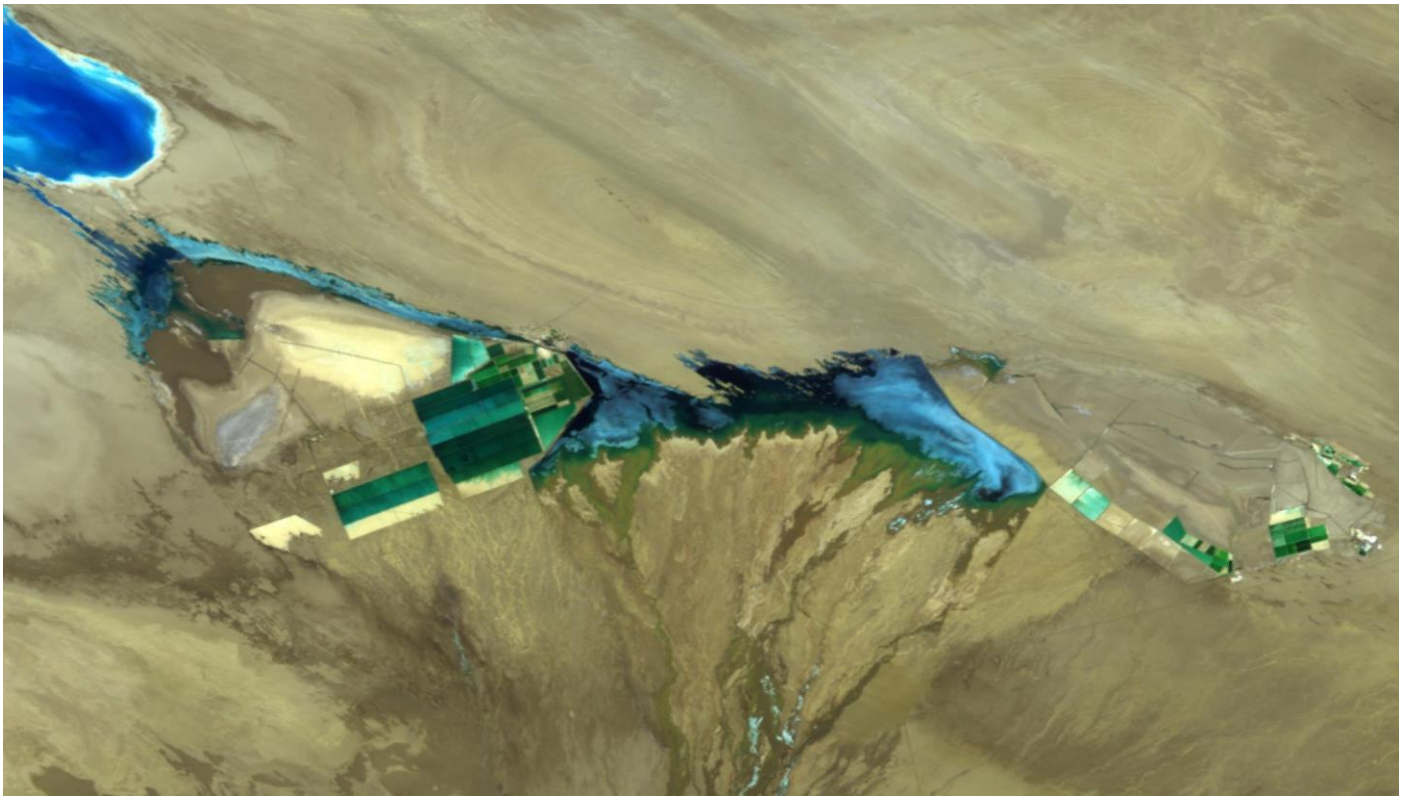
33. PROBAV_S1_TOA_X27Y03_20140321_100M_V101 (Dabuxun Lake, Northwest of China)

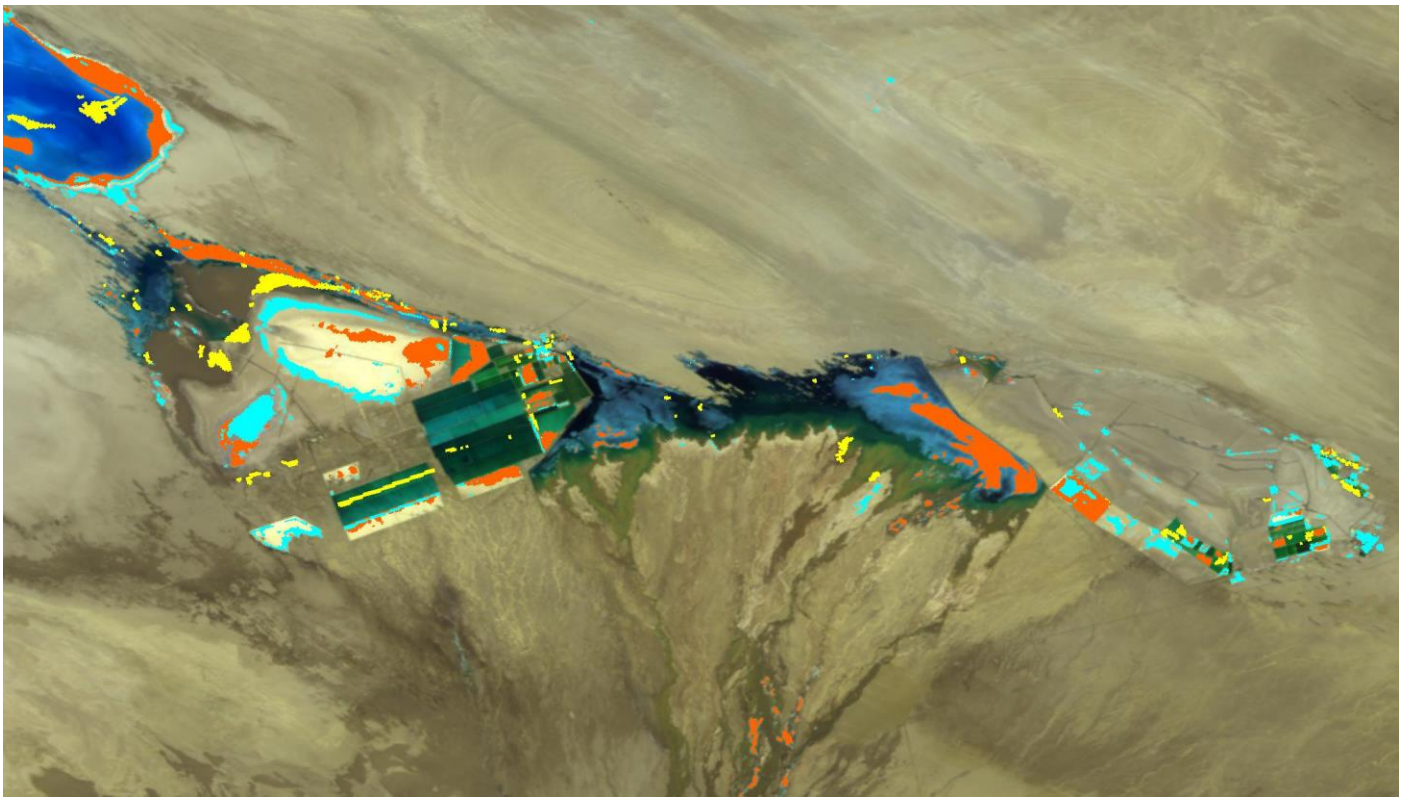




As already mentioned, the sand that lies on the shores of the lakes (and is probably humid to varying degrees) is marked with a cloud mask (more rarely with a snow mask). The shallow water that lies over the sandbank, which may be overgrown with algae/aquatic plants, and appears somewhat bluish, is on the contrary marked oftener with an ice mask then with a cloud mask. The same applies to some objects of artificial origin.
Pictures №33, №34 illustrate this statement.

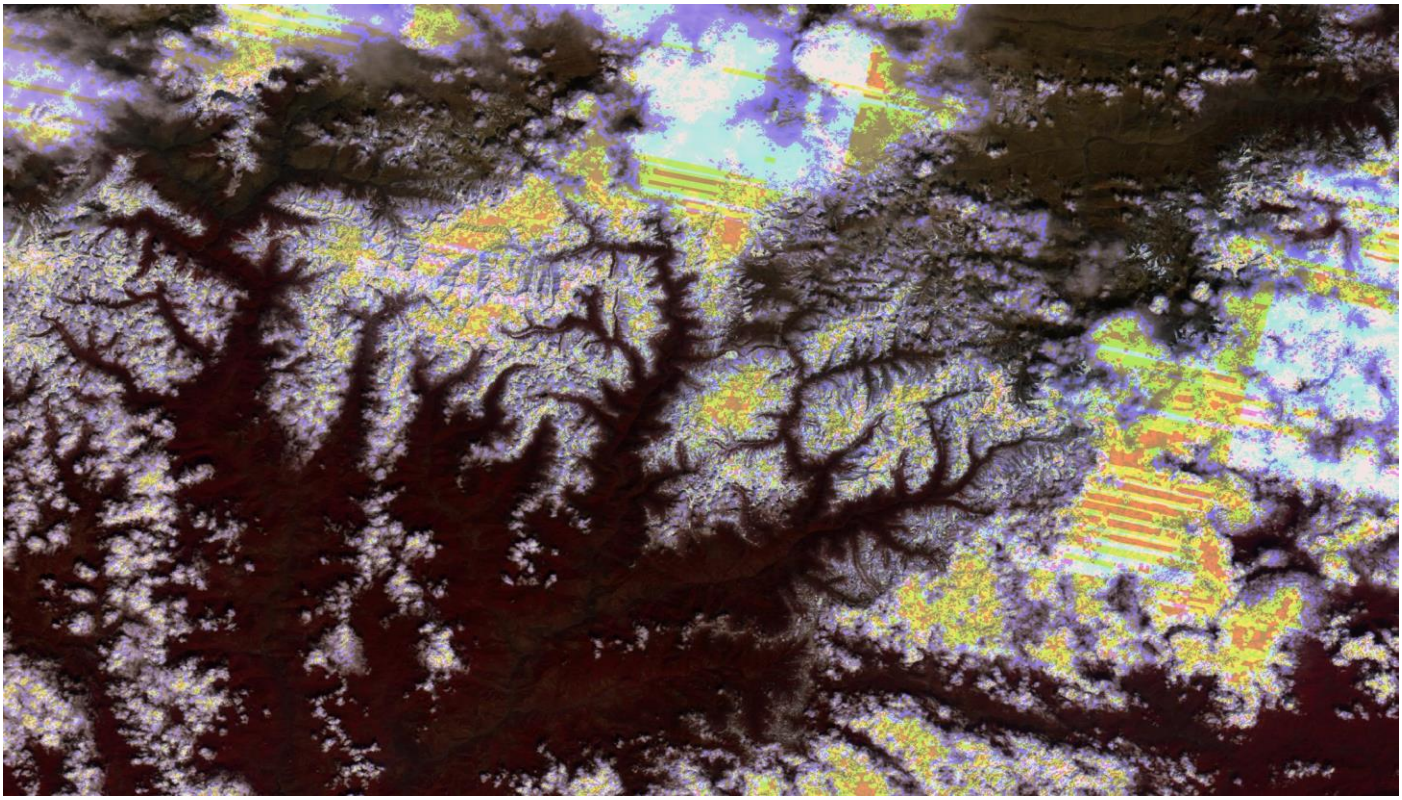
34. Zoomed detail from the same fragment (West Taiji Nai'er Lake)

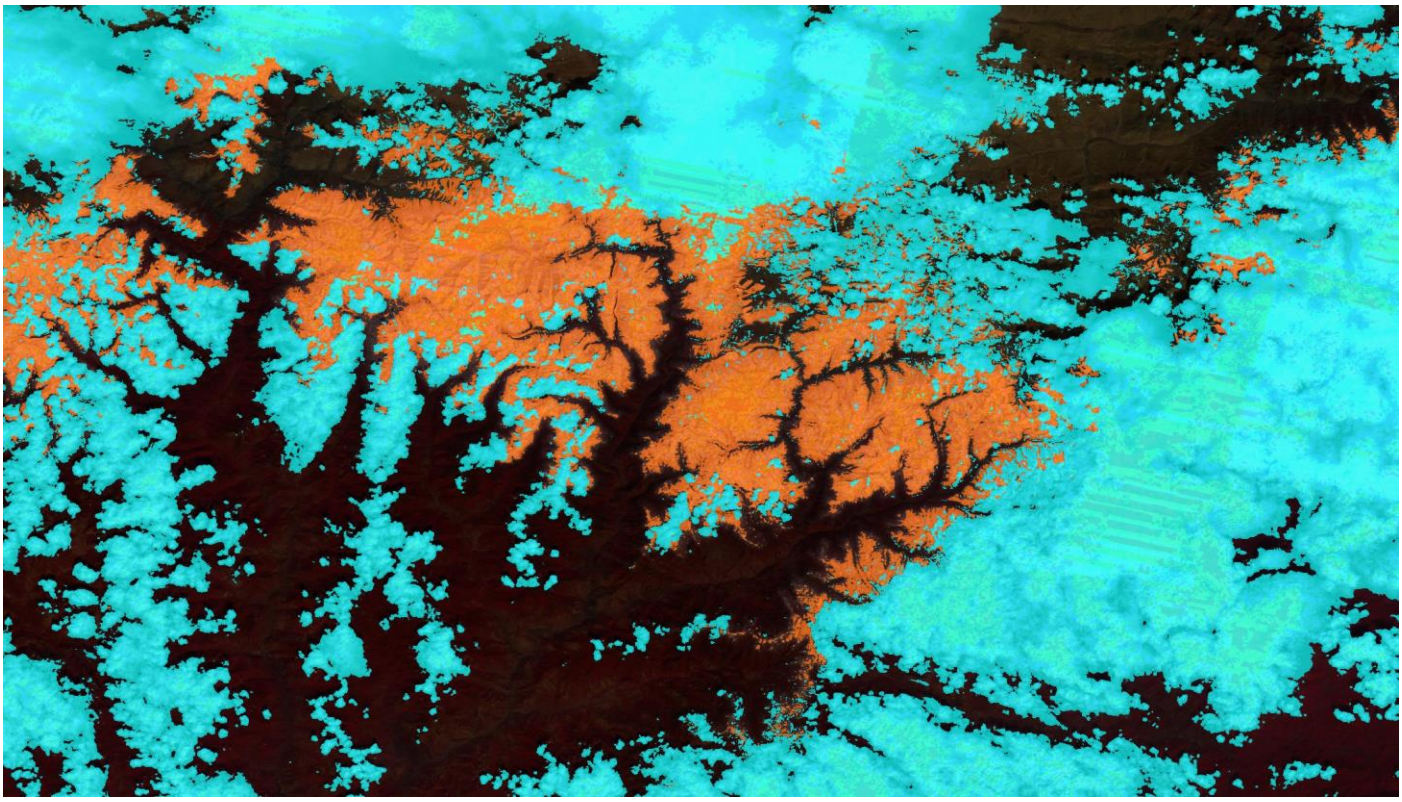




See description to the previous page (№33).

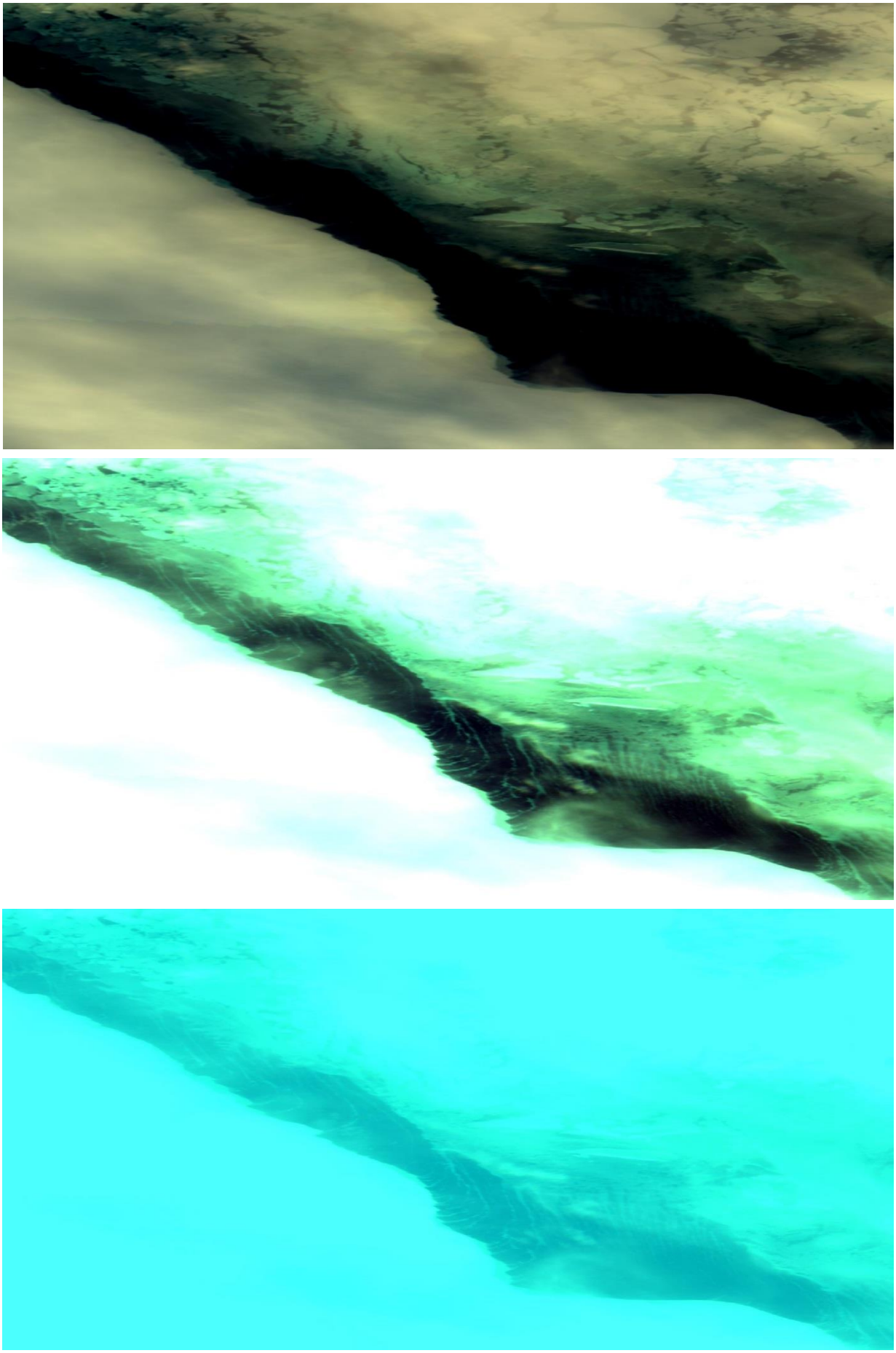
35. PROBAV_S1_TOA_X27Y04_20140321_100M_V101 (East Tibet)





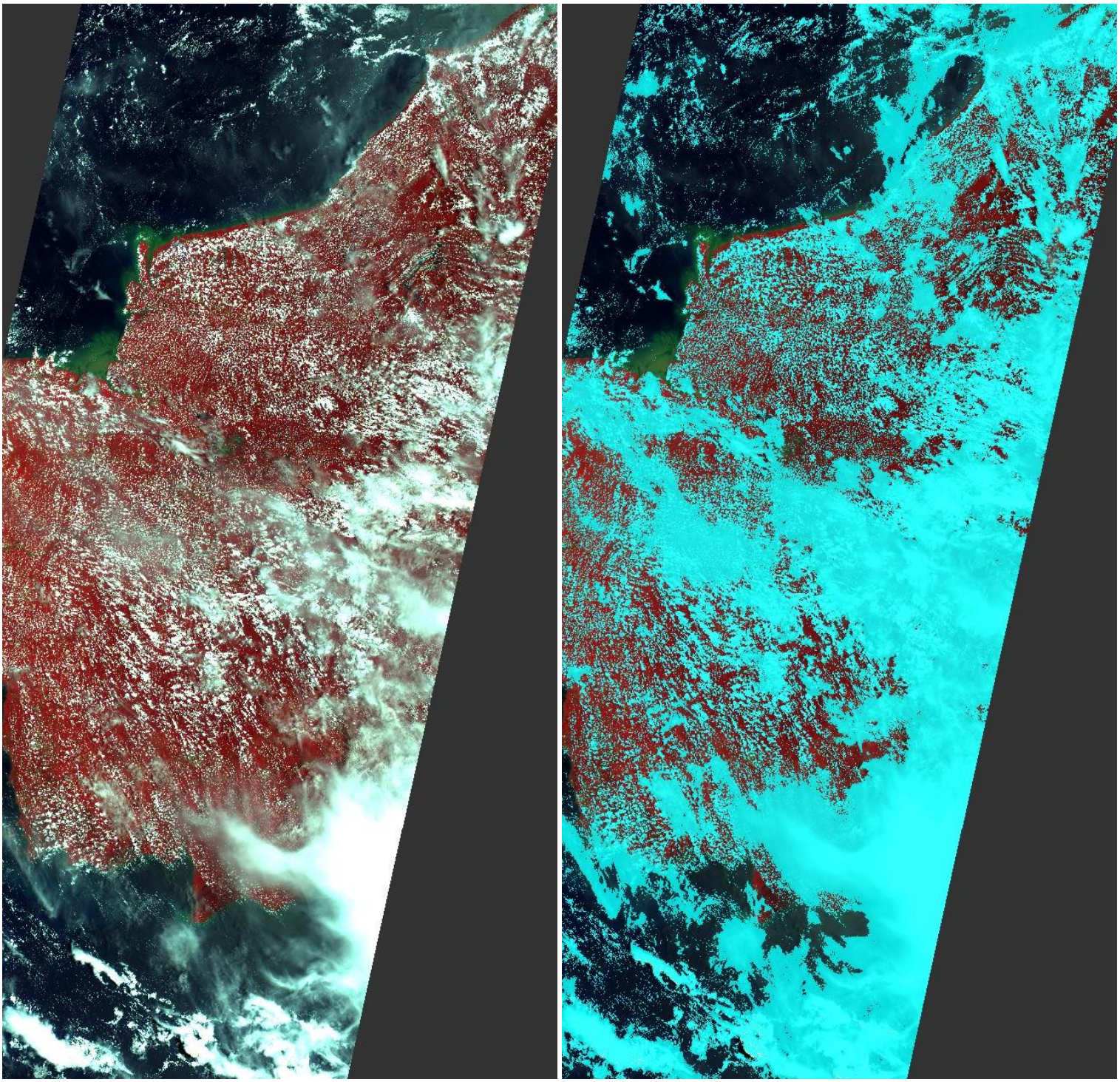
Taking into account of premade fixation of "damaged" pixels from "NOT SO GOOD" flags, the cloud and snow masks turned out well.

36. PROBAV_S1_TOA_X29Y00_20140321_100M_V101 (Laptev Sea)



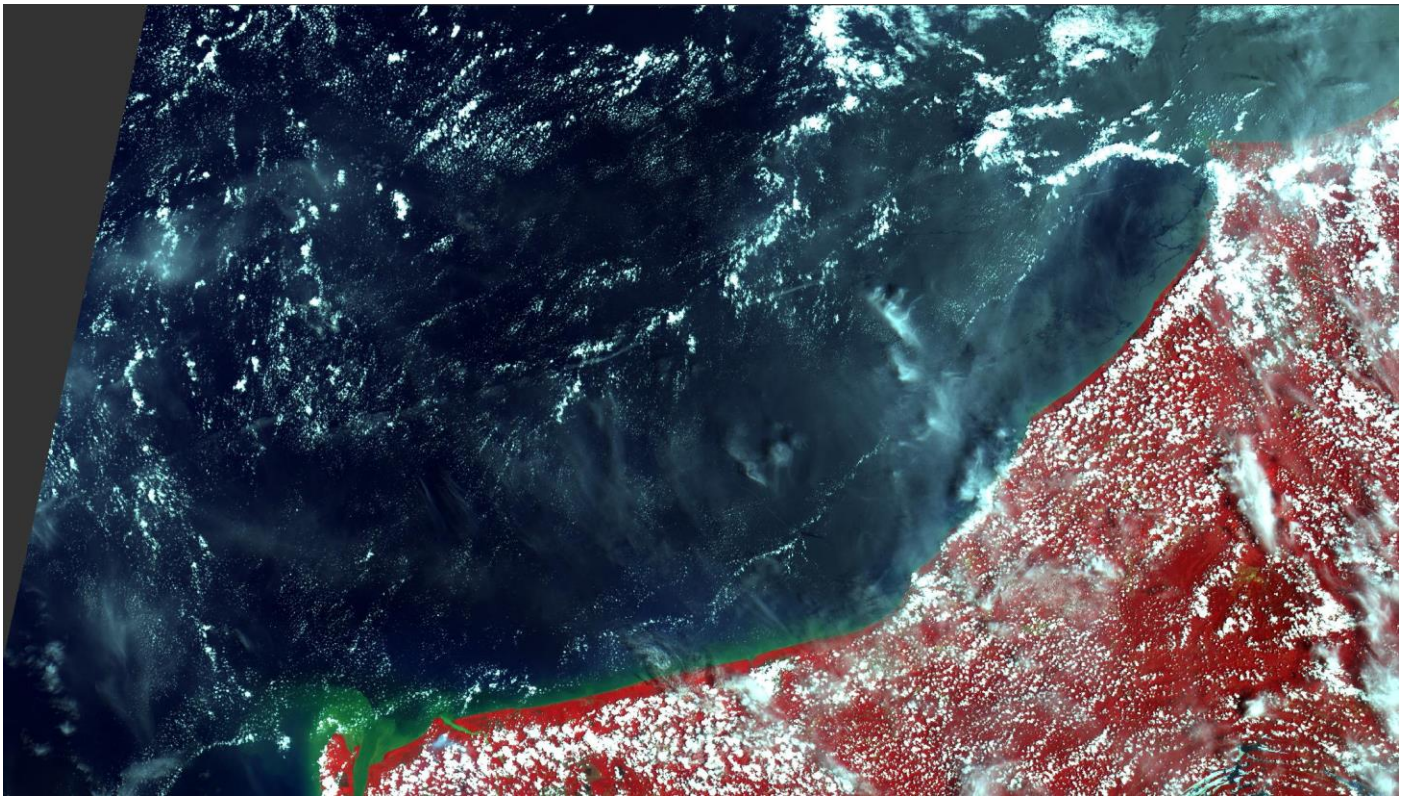
Floating sea ice and some pixels of cloud- and ice free water - all of this was incorrectly marked as cloudy (blue).

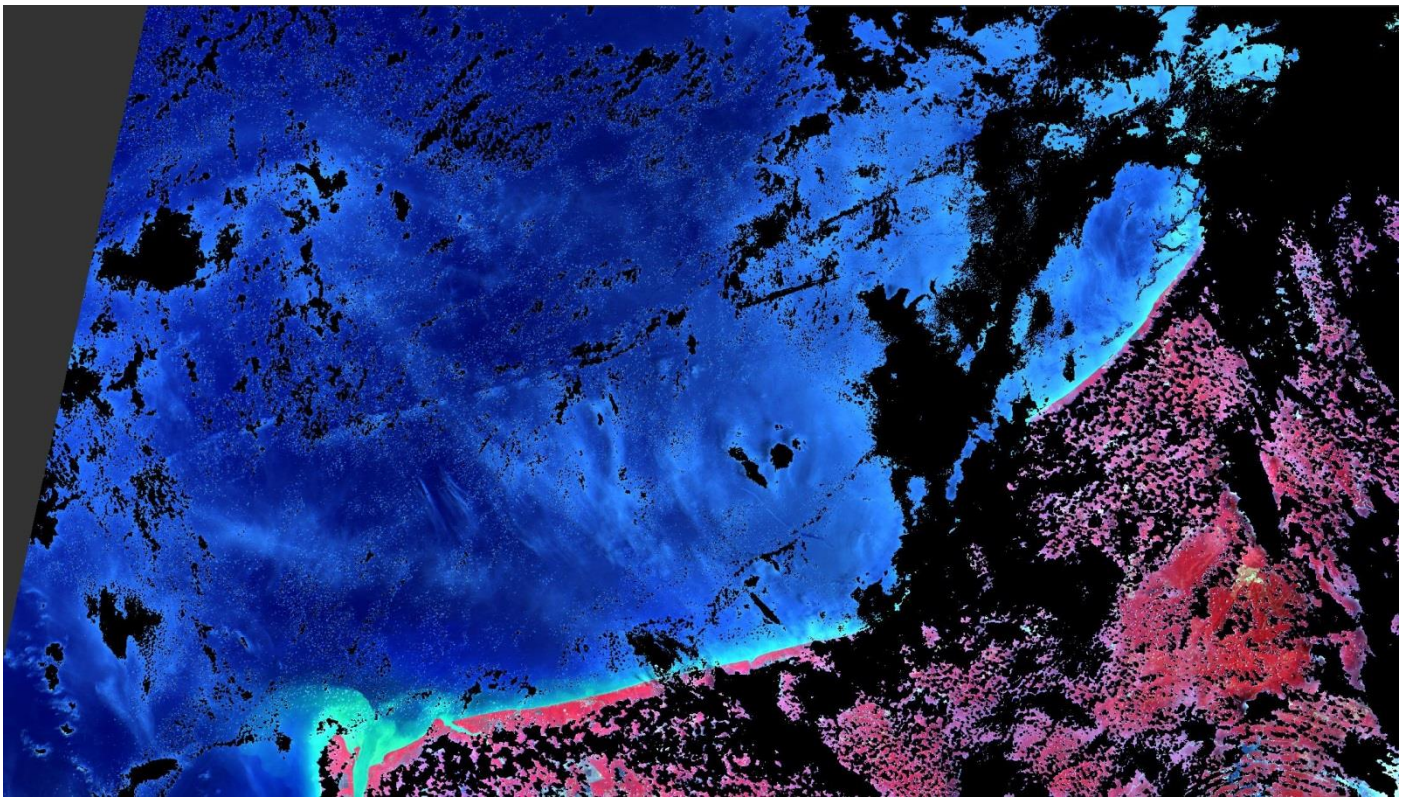
37. PROBAV_S1_TOA_X29Y07_20140321_100M_V101 (West Kalimantan)



A well done cloud mask.

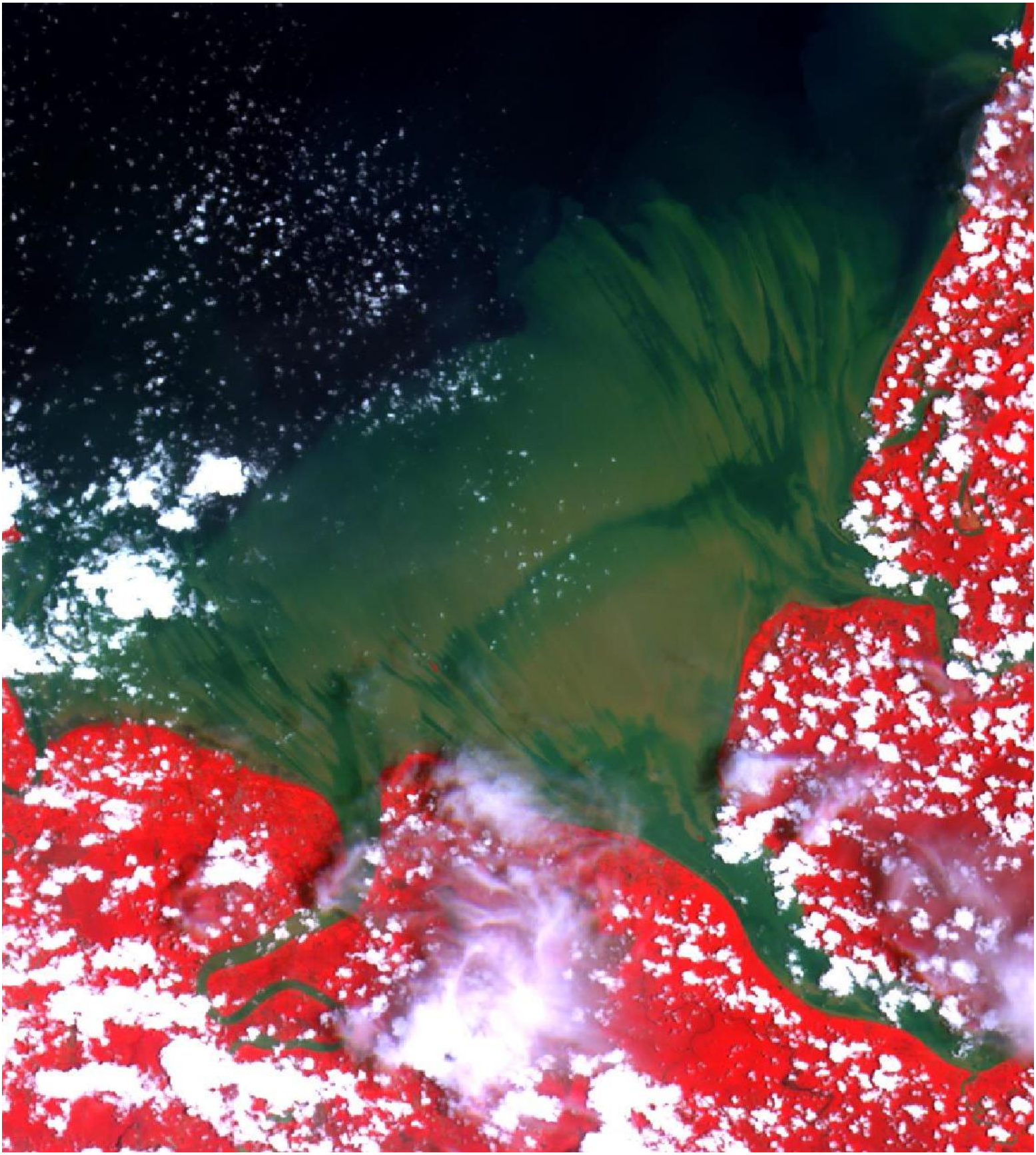
38. Zoomed detail from the same fragment (In the Northeast of Rejang River Estuary)





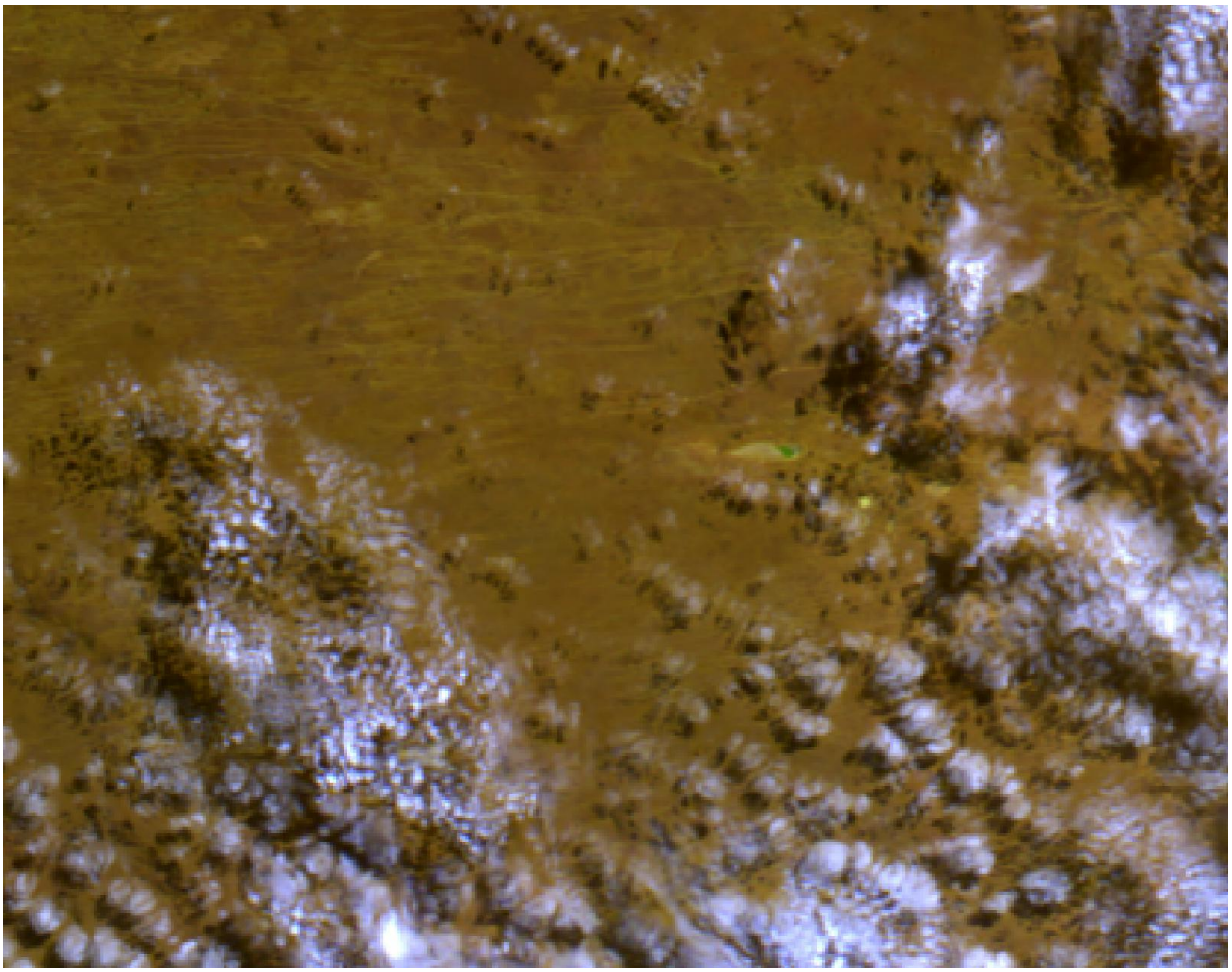
However (see №37), some very thin, semi-transparent clouds have not been recognized.
(Here cloud mask - black for better contrast)

39. Zoomed detail from the same fragment (Teluk Sangki Bay, Sarawak)

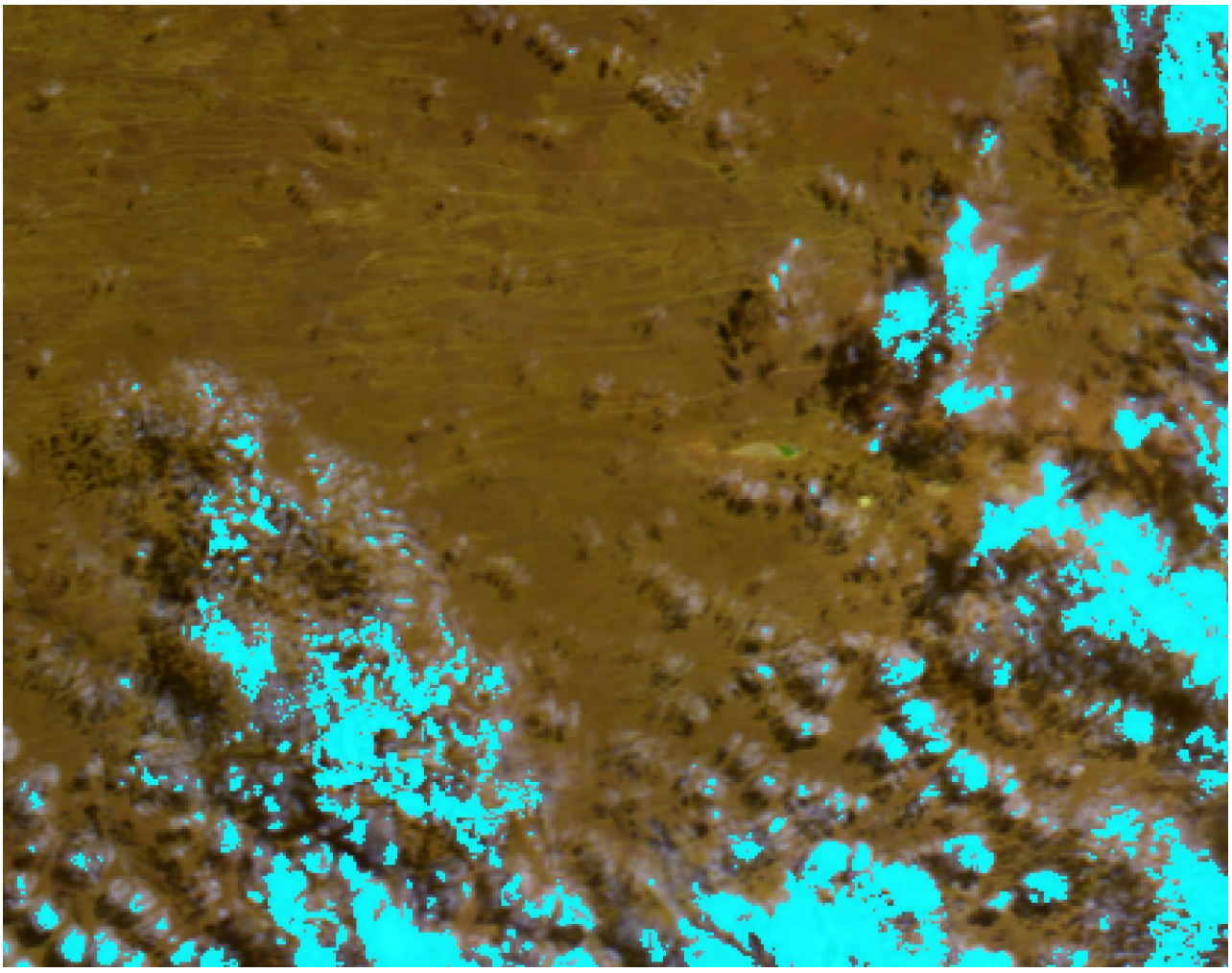


Beautiful picture

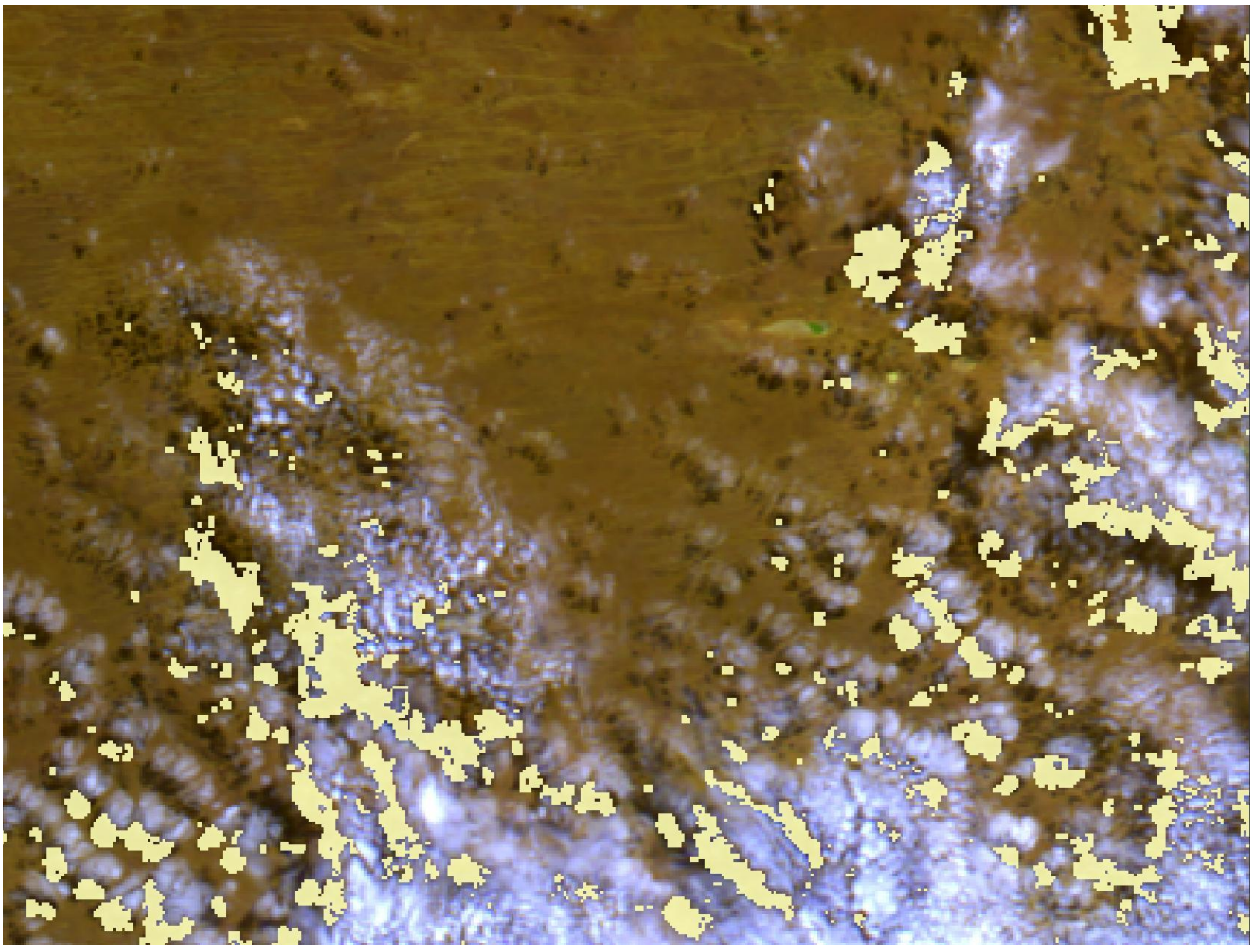
40. PROBAV_S1_TOA_X30Y10_20140321_100M_V101 (South of West Australia)



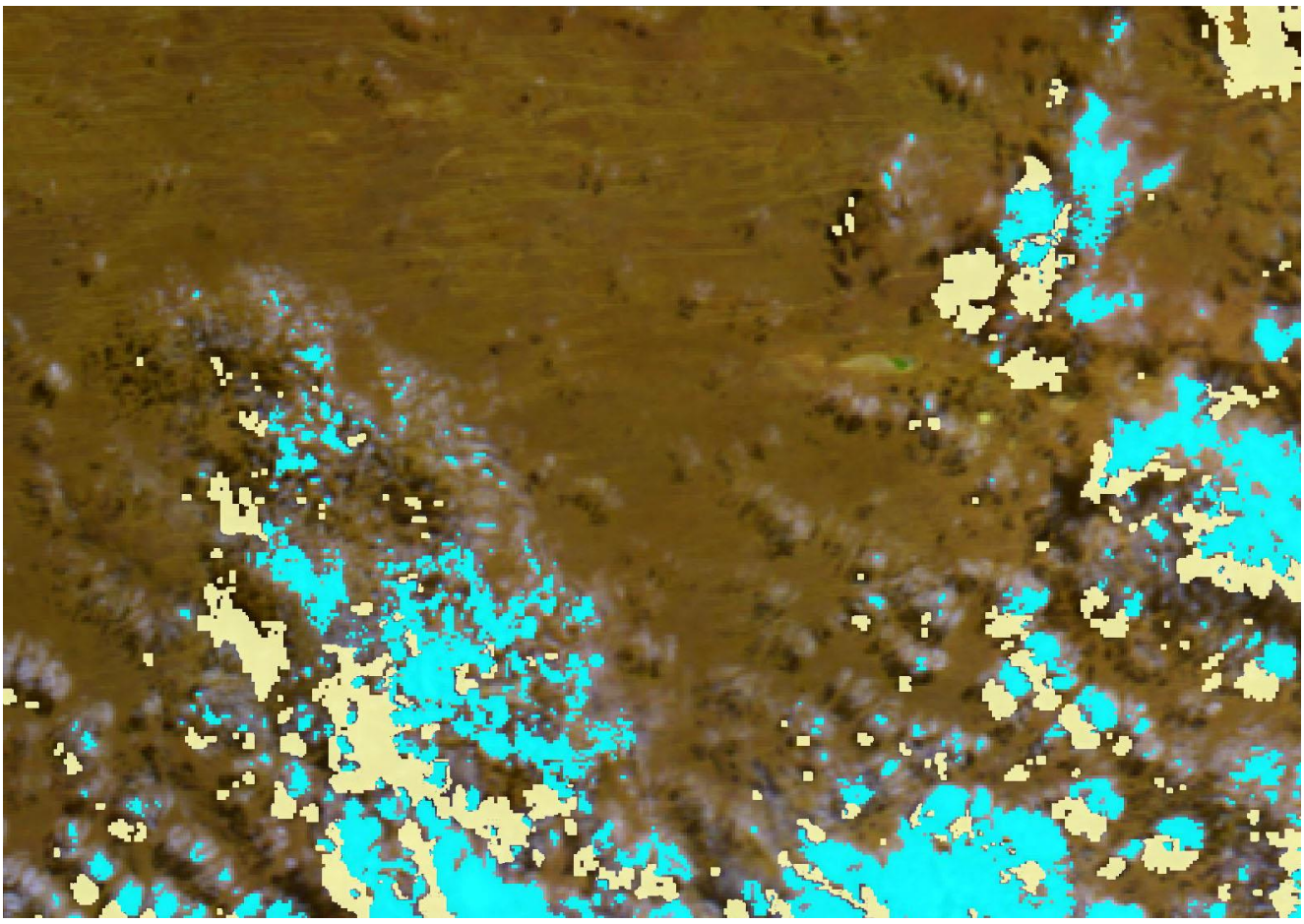
a



b



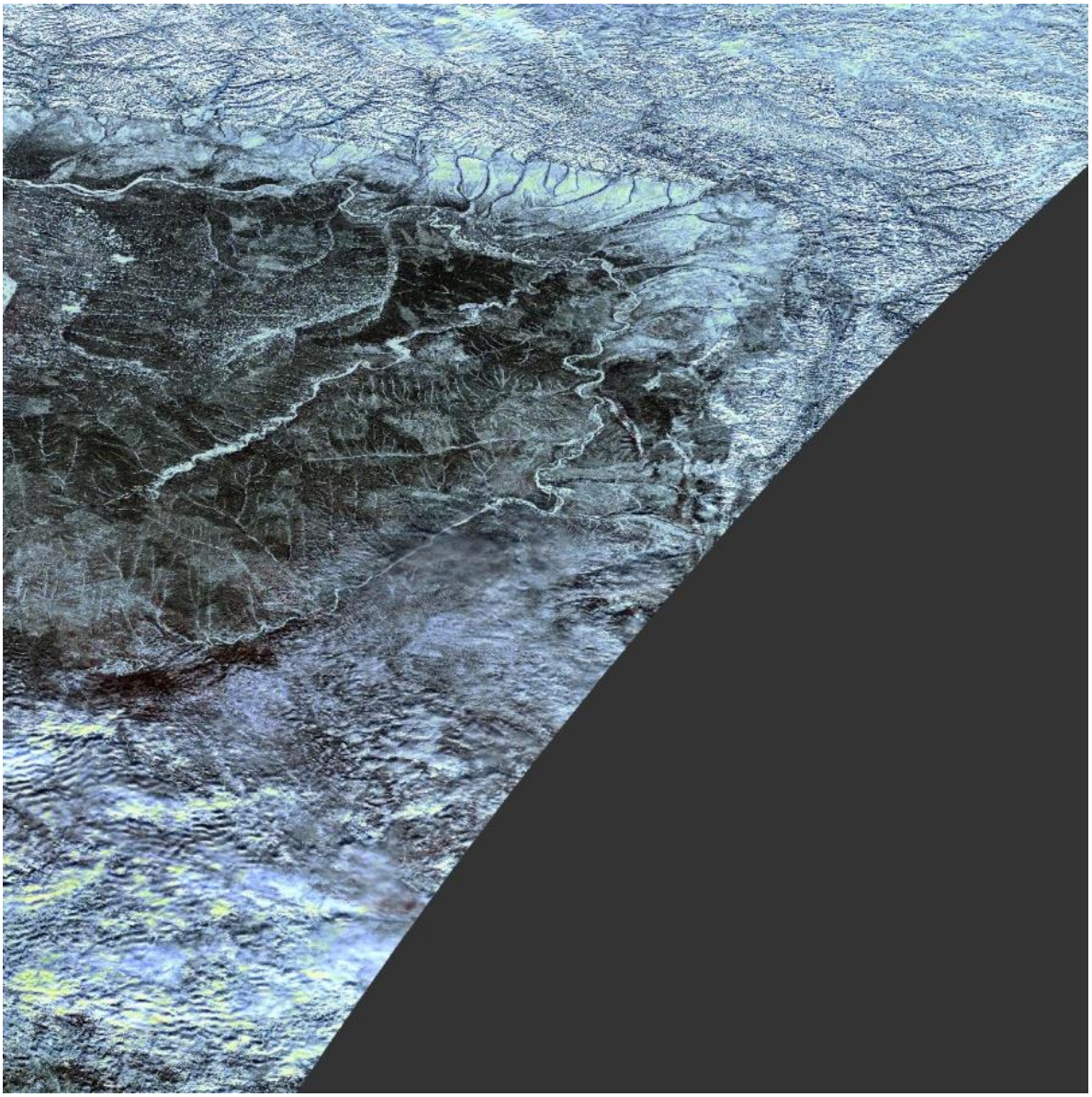
c

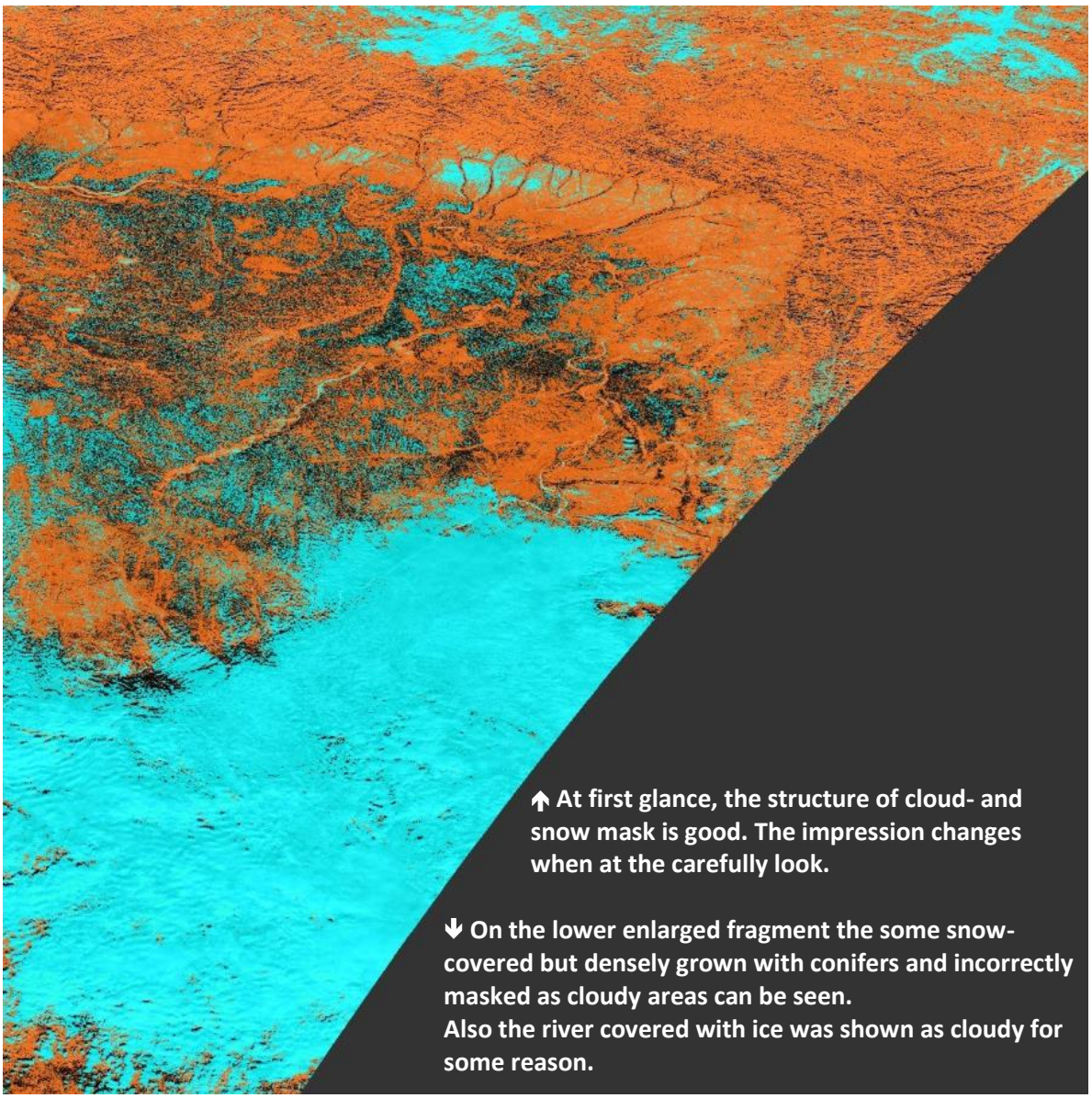


d

Small semi-transparent Cumulus clouds and their edges have not been masked as clouds ("b").
The height of some clouds was incorrectly estimated, hence sometimes incorrectly placed shadow masks ("c").

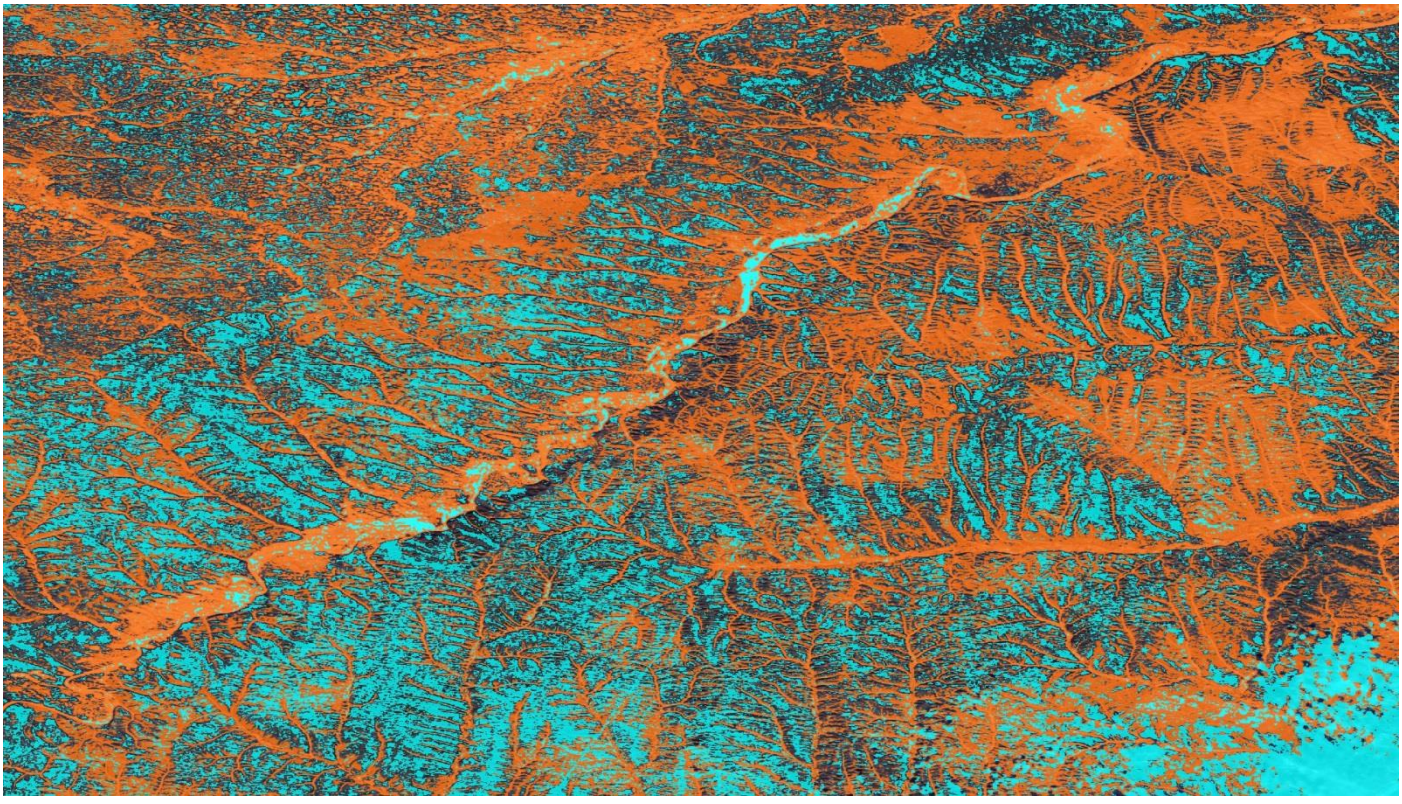
41. PROBAV_S1_TOA_X31Y01_20140321_100M_V101 (Yakutia, Amga River, Russia)



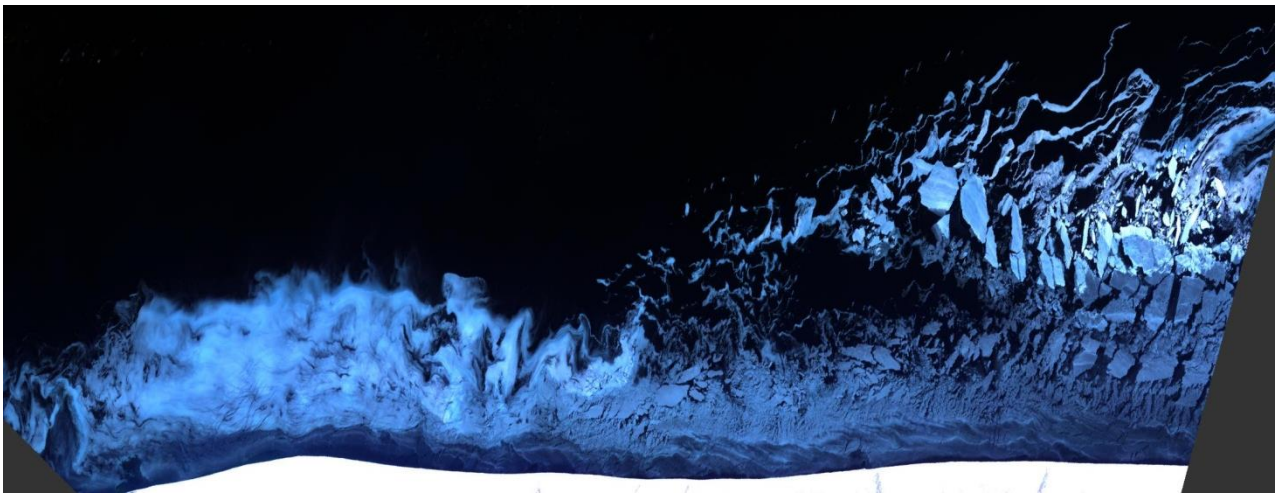


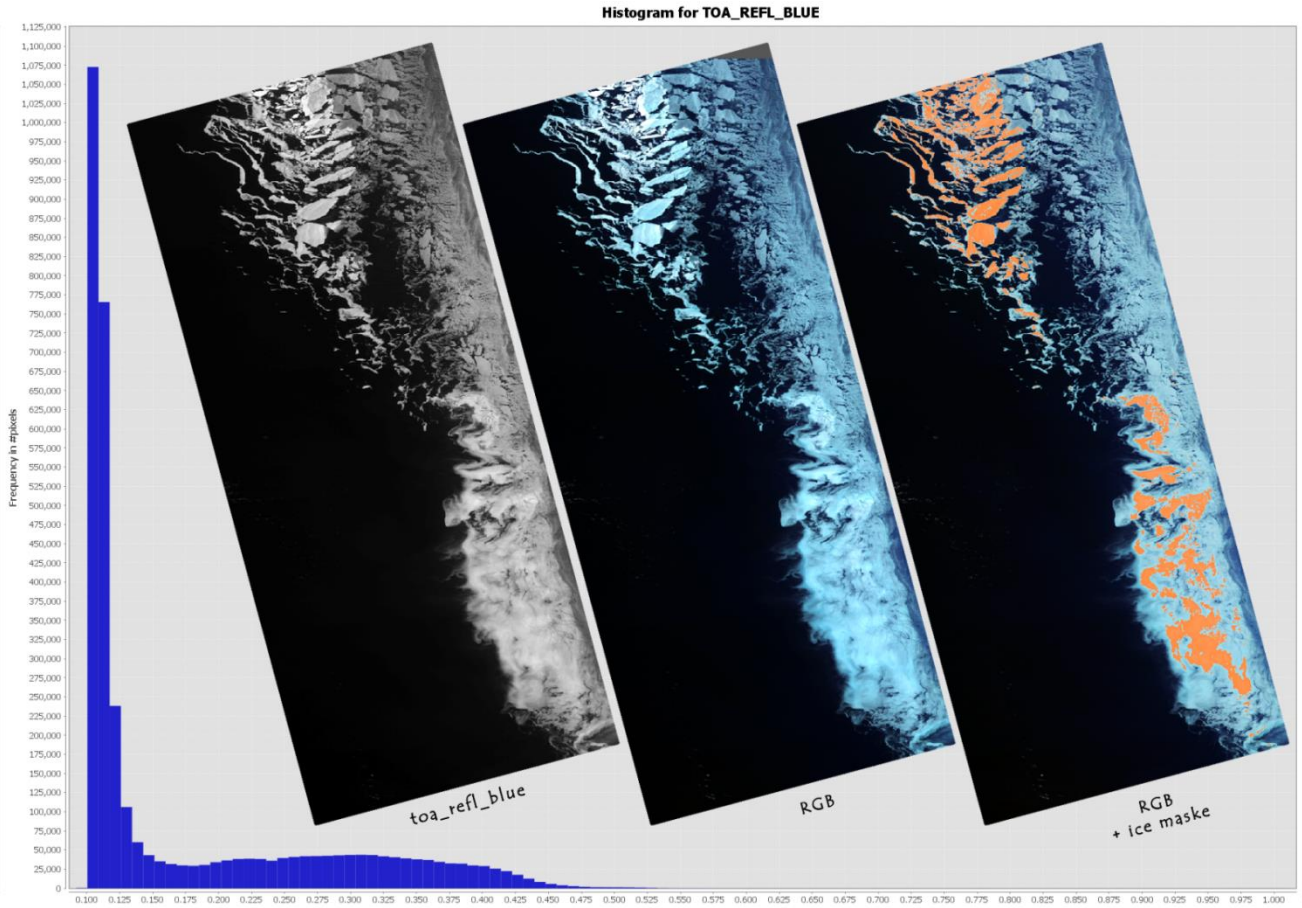
↑ At first glance, the structure of cloud- and snow mask is good. The impression changes when at the carefully look.

↓ On the lower enlarged fragment the some snow-covered but densely grown with conifers and incorrectly masked as cloudy areas can be seen.
Also the river covered with ice was shown as cloudy for some reason.



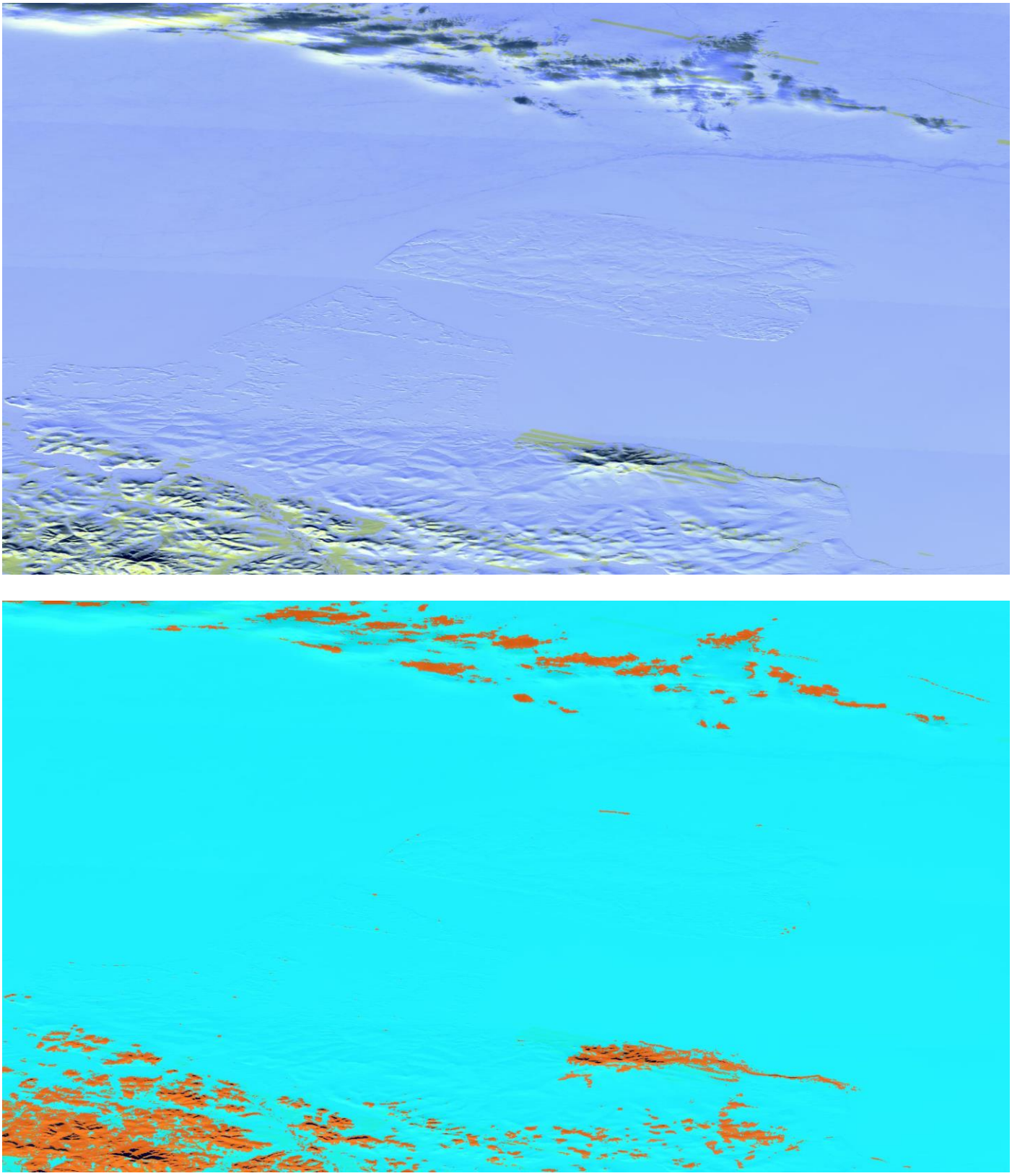
42. PROBAV_S1_TOA_X33Y02_20140321_100M_V101 (Sea of Okhotsk close to the Southwest of Kamchatka)





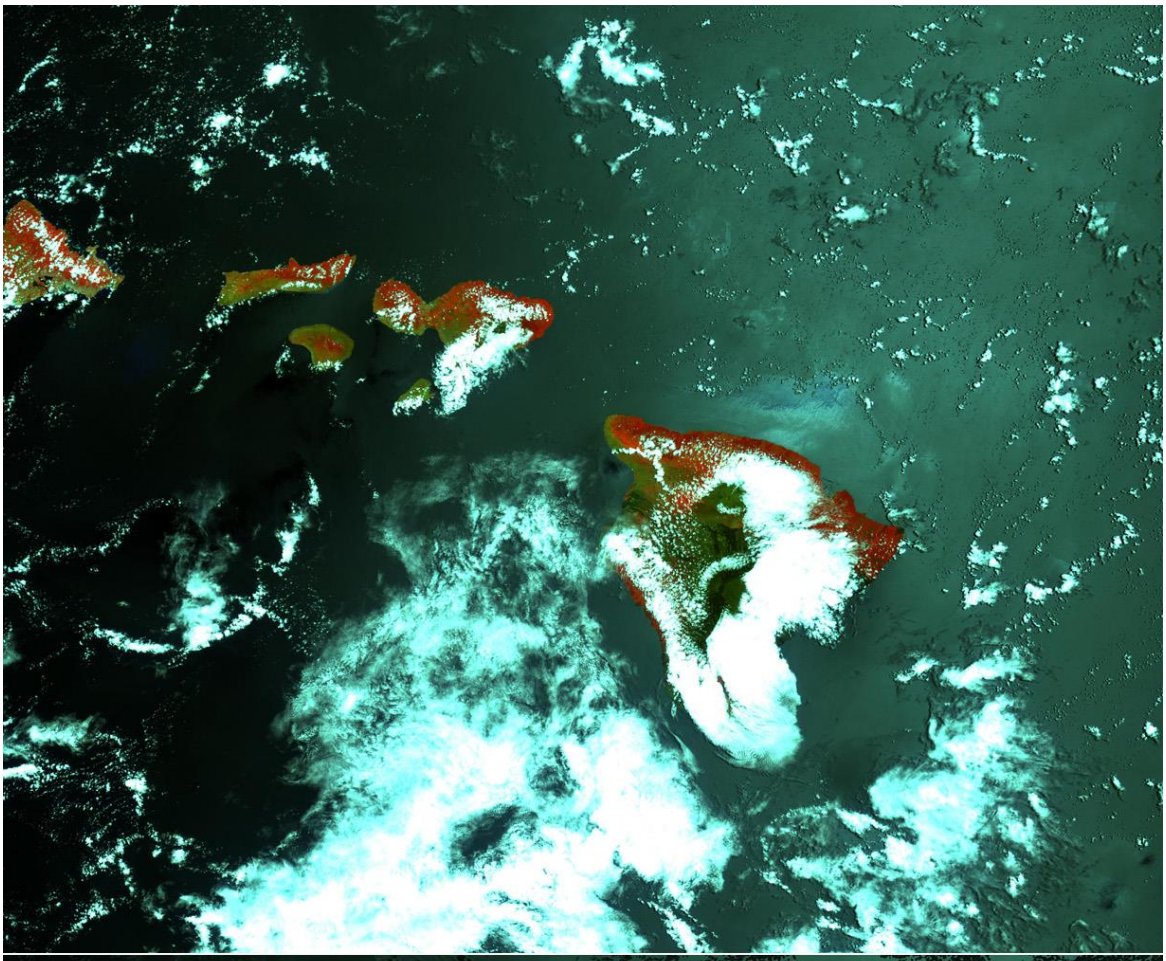
As with case 9 (where it was all about semi-transparent clouds over the water), this case is about sea ice, but the problem remains the same. The sea floating ice was only partially recognized as such, although the local two-dimensional approach with a local threshold of 1.3 could help quickly and easily (as the histogram proves).

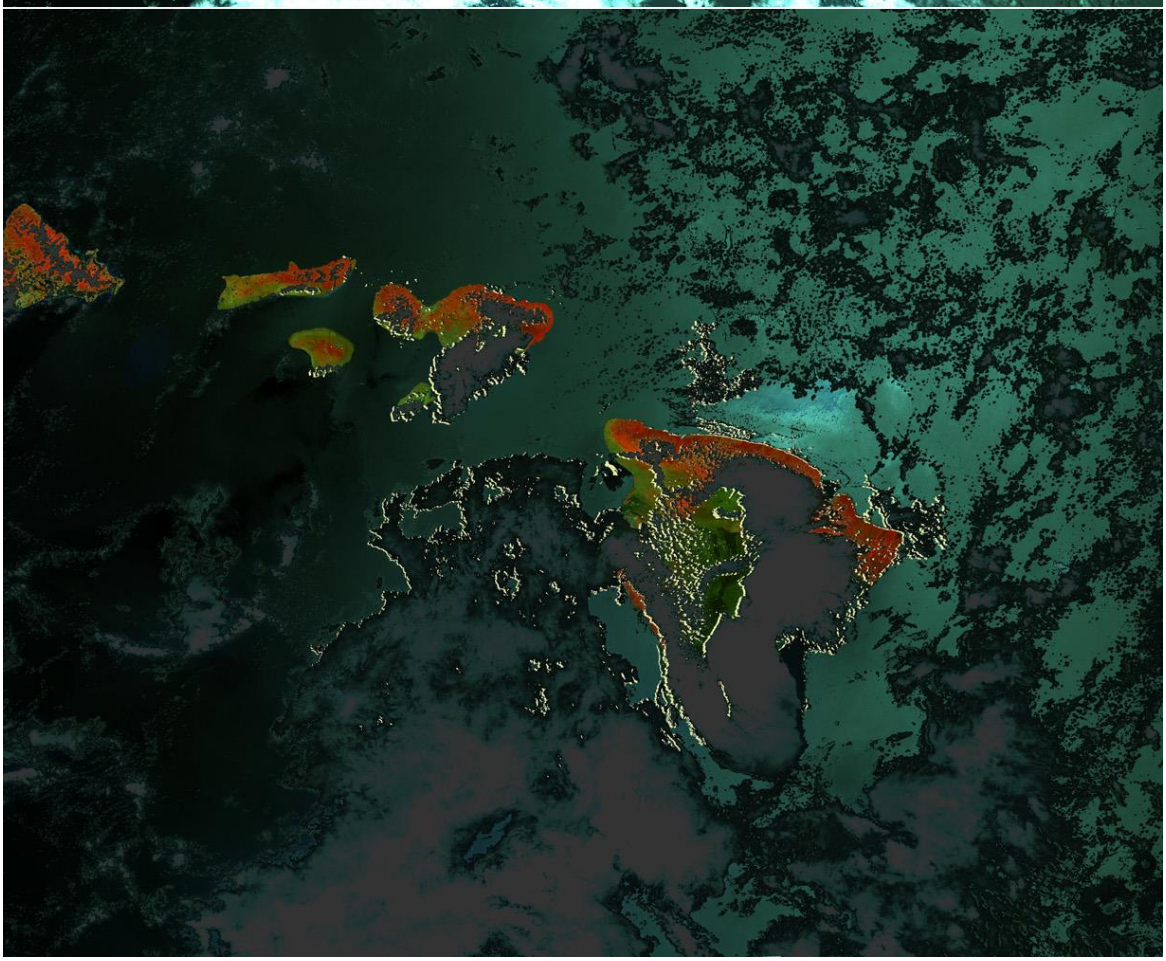
43. PROBAV_S1_TOA_X34Y00_20140321_100M_V101 (East Siberian Sea)



The cloud mask is almost completely wrong over this region. On the picture (top) the continental ice can be seen under a clear sky. As with many other cases in polar latitudes, the cloud-ice mask (bottom) fails over the bright ice.

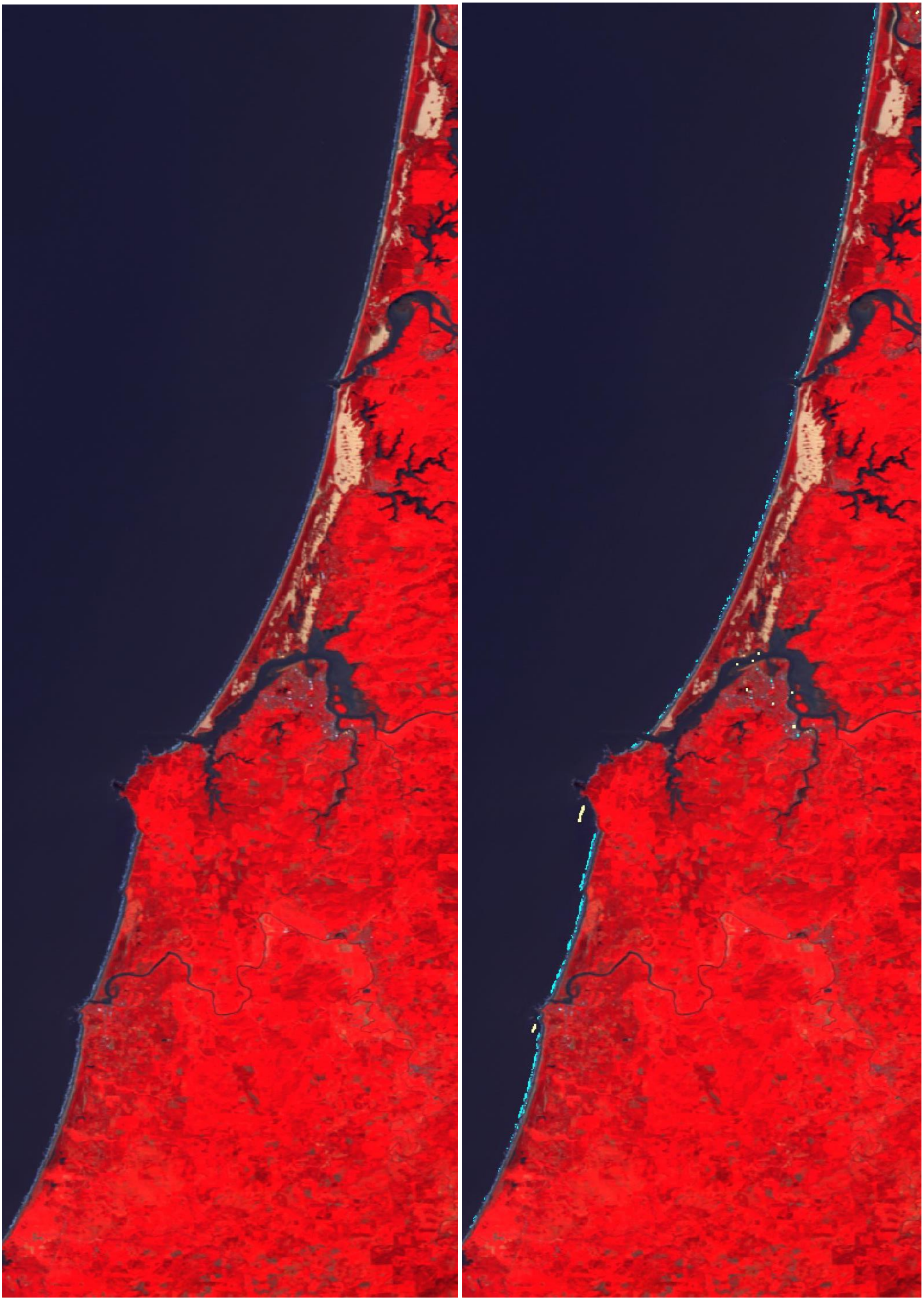
44. PROBAV_S1_TOA_X02Y05_20140621_100M_V101 (Hawaii)





Many sun glint pixels were not recognize as such rather as clouds (black cloud mask). Shadows were not shown everywhere.

45. PROBAV_S1_TOA_X05Y03_20140621_100M_V101 (Pacific Ocean in the West of North California)

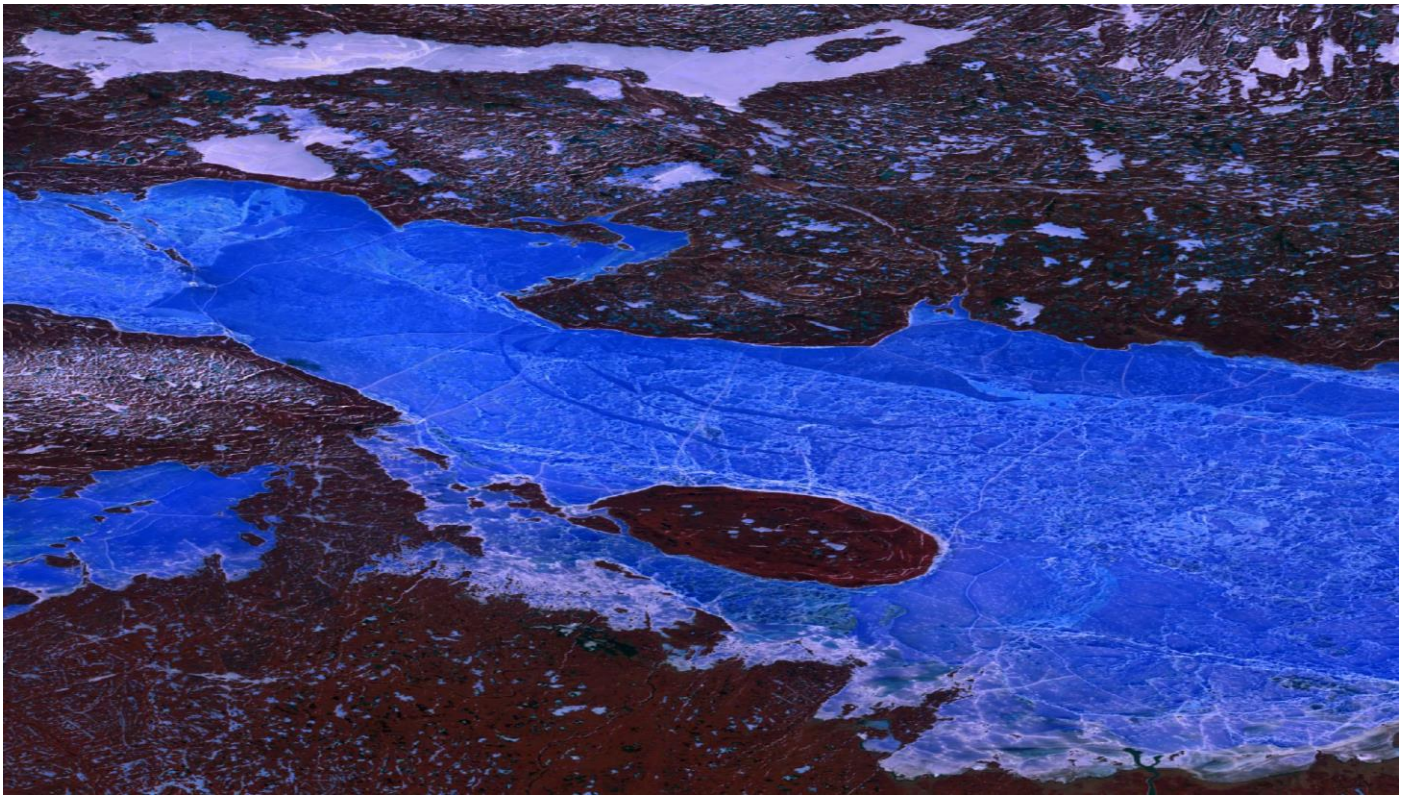


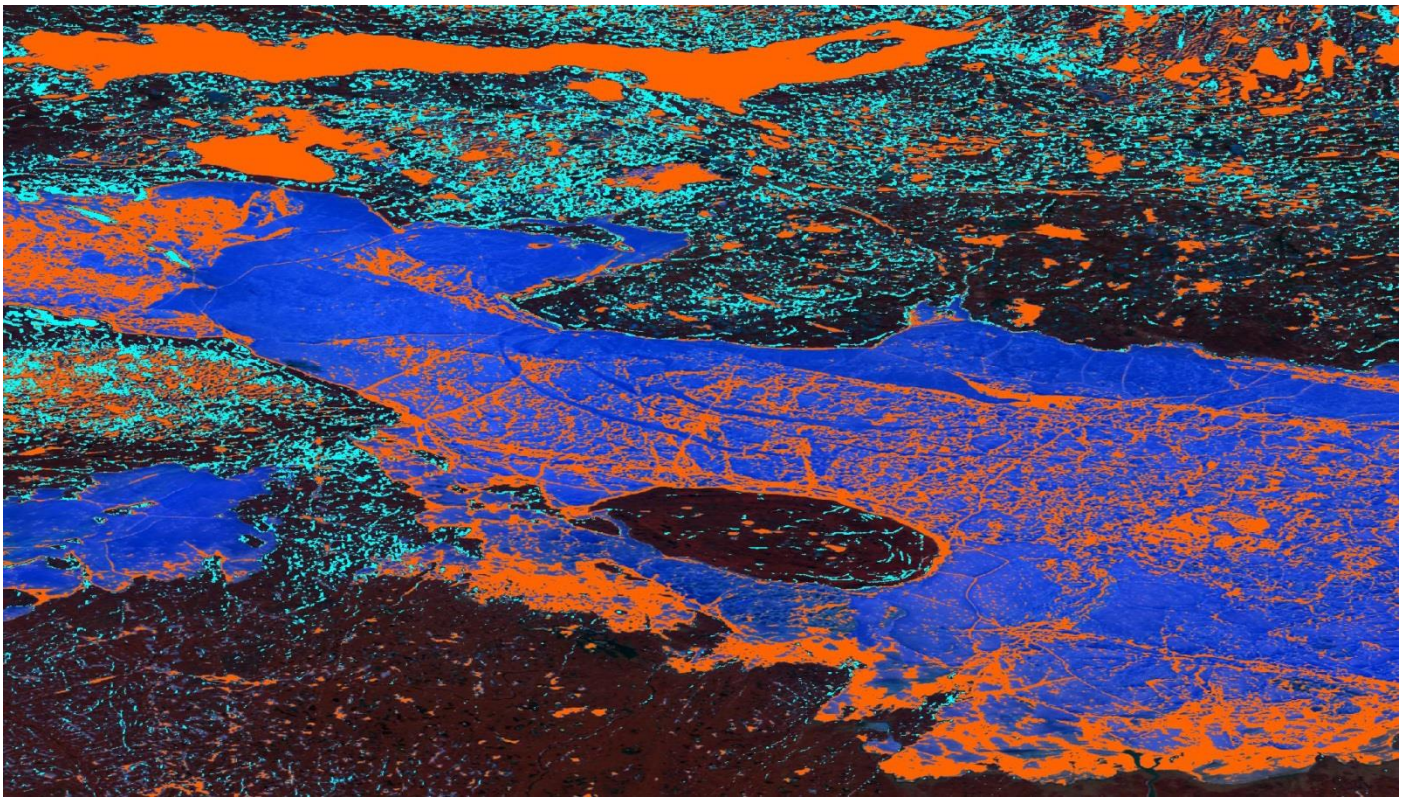
46. PROBAV_S1_TOA_X05Y03_20140621_100M_V101 (North California)

↑ Description to № 46. The region consists of land, snow and no shadows and is completely covered with semi-transparent clouds. The masking is colorful, but often not correct.

← Description to № 45. Sandy coast was incorrectly identified as cloudy. Even cloud shadows that did not exist were calculated.

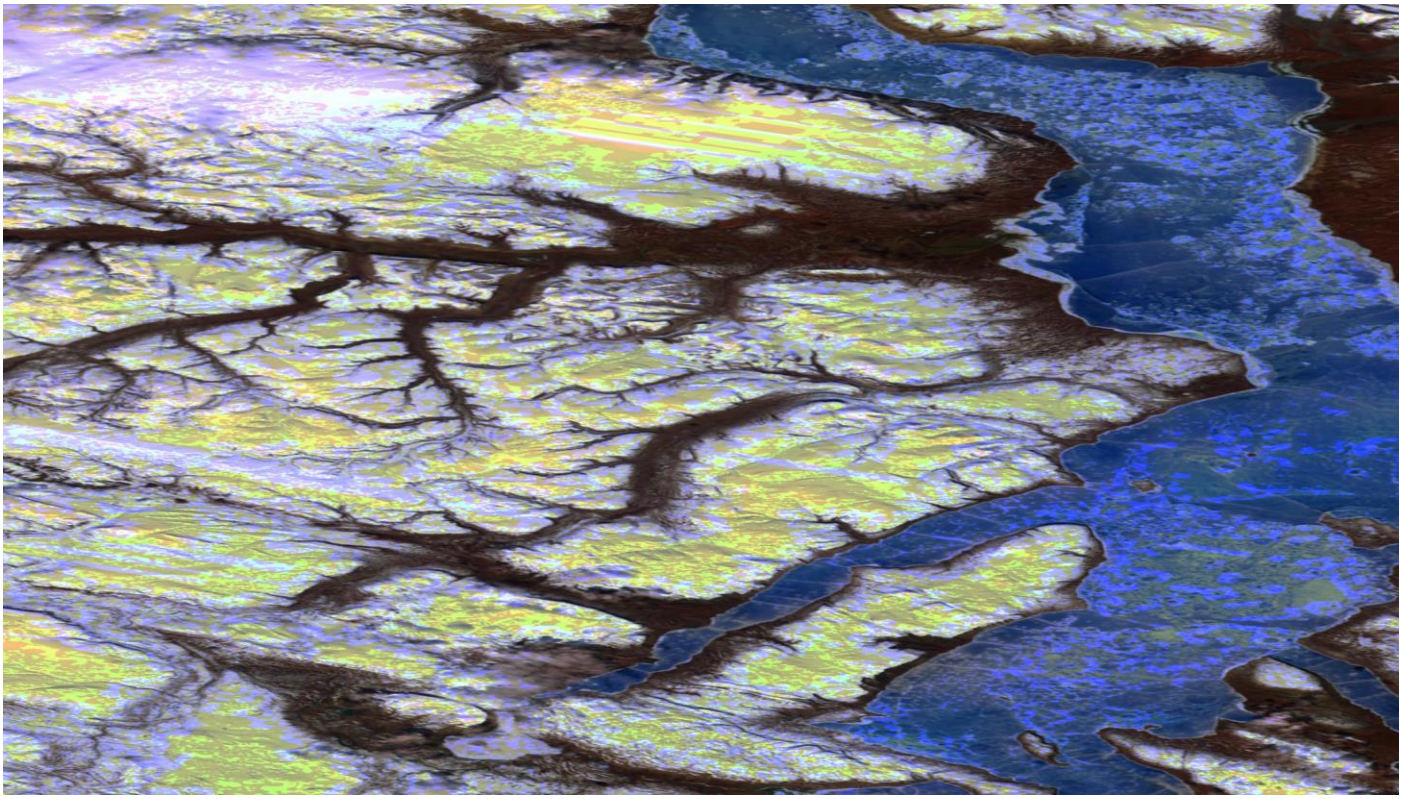
47. PROBAV_S1_TOA_X07Y00_20140621_100M_V101 (Dease Strait, Queen Maud Gulf, Melbourne Island, Canada)

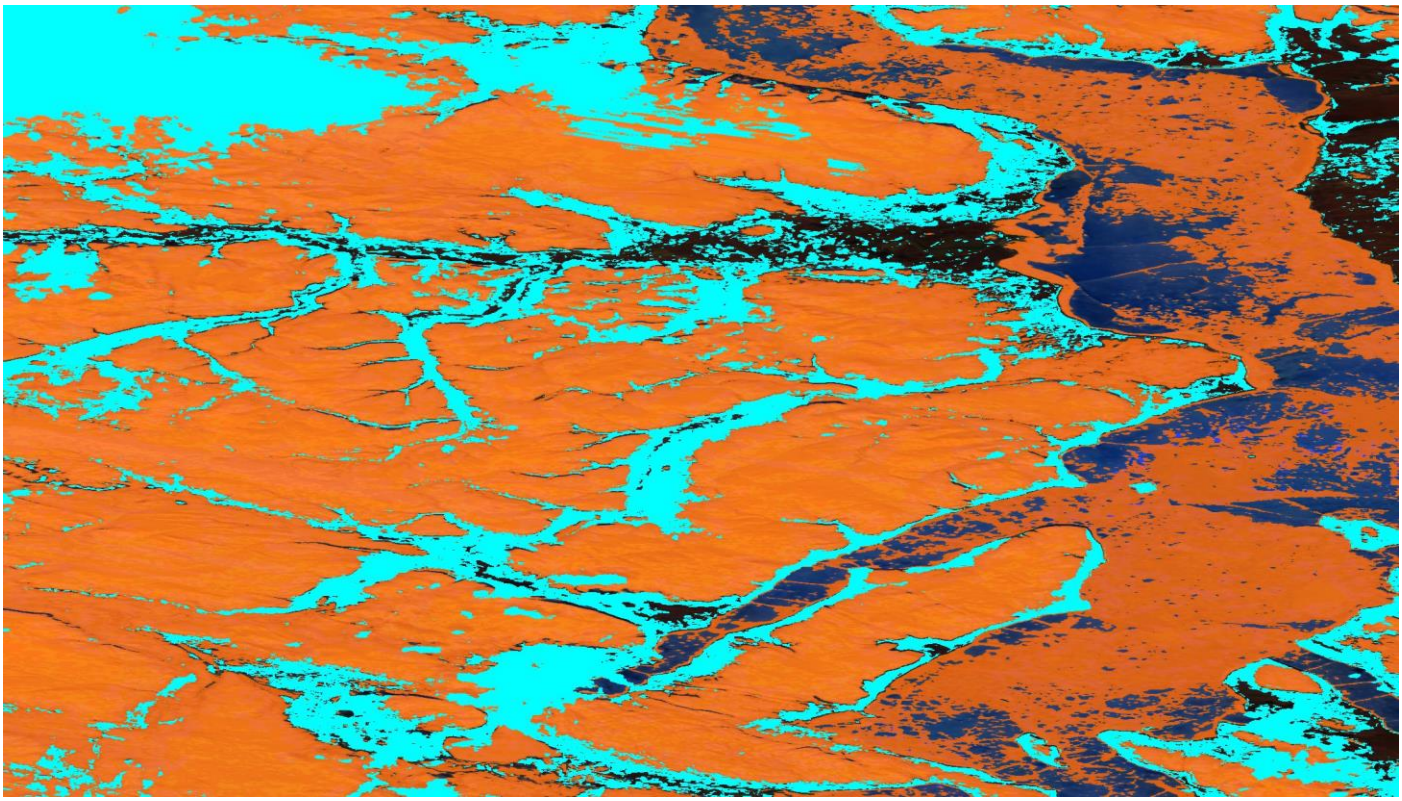




Lakes are completely covered with different types of ice. Unfortunately, this does not reflect when masking. Relative dark ice was not masked.
Areas partially covered with snow (probably forest) are mostly incorrectly identified as cloudy.

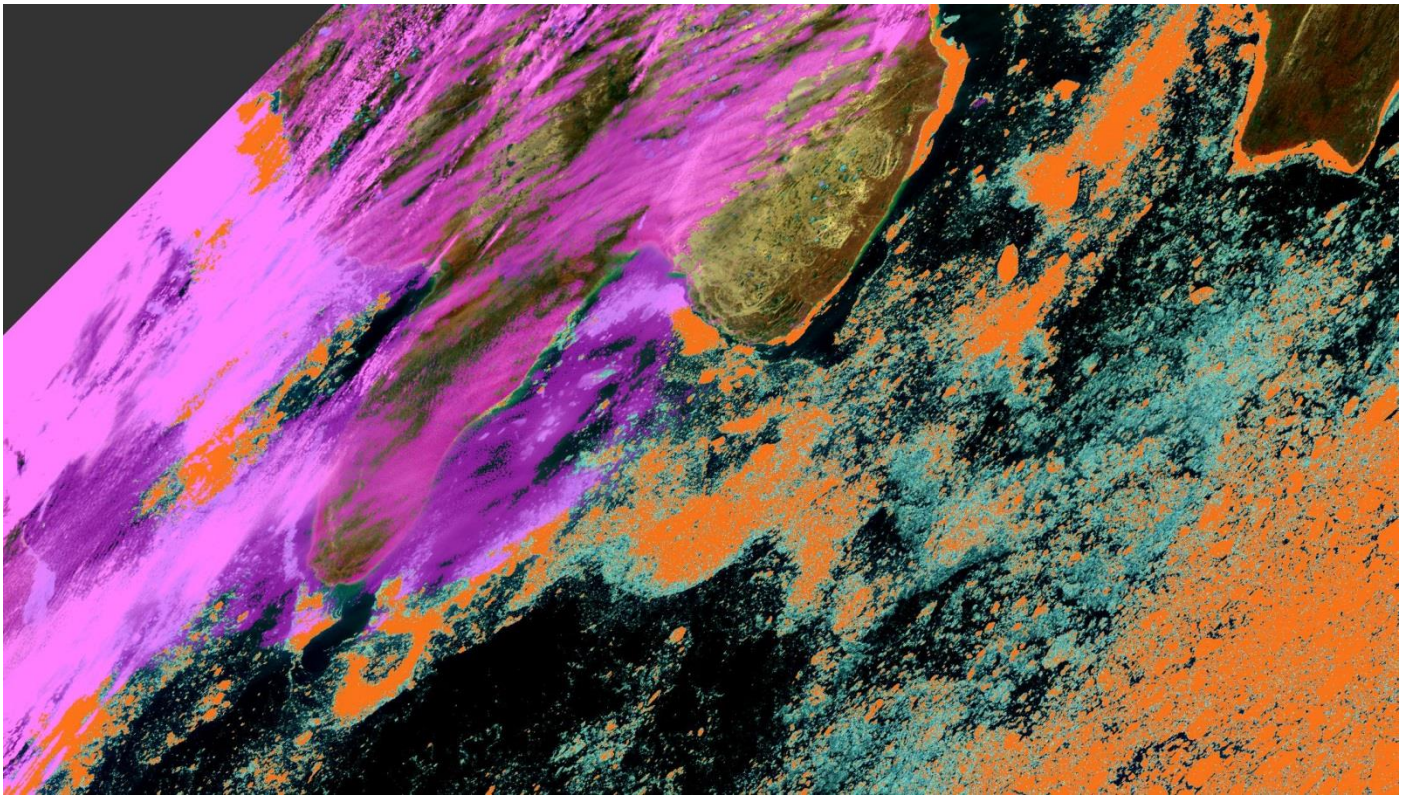
48. PROBAV_S1_TOA_X09Y00_20140621_100M_V101 (North of Baffin Island, Eclipse Sound, Bylot Island)

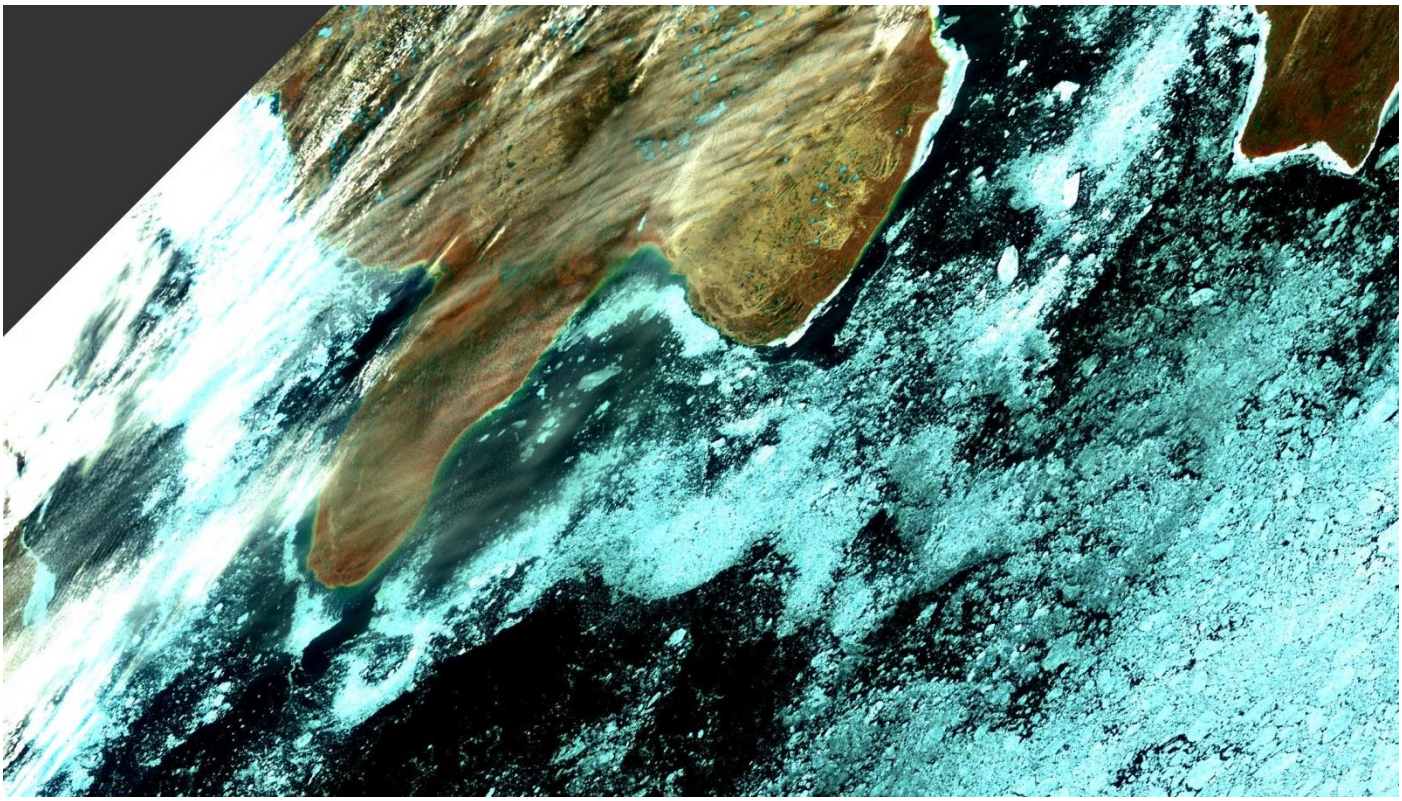




Among other mistakes, the cloud-free valleys, probably overgrown with forest, presumably with snow covered soil to varying degrees, were mostly thought (and masked) to be cloudy.

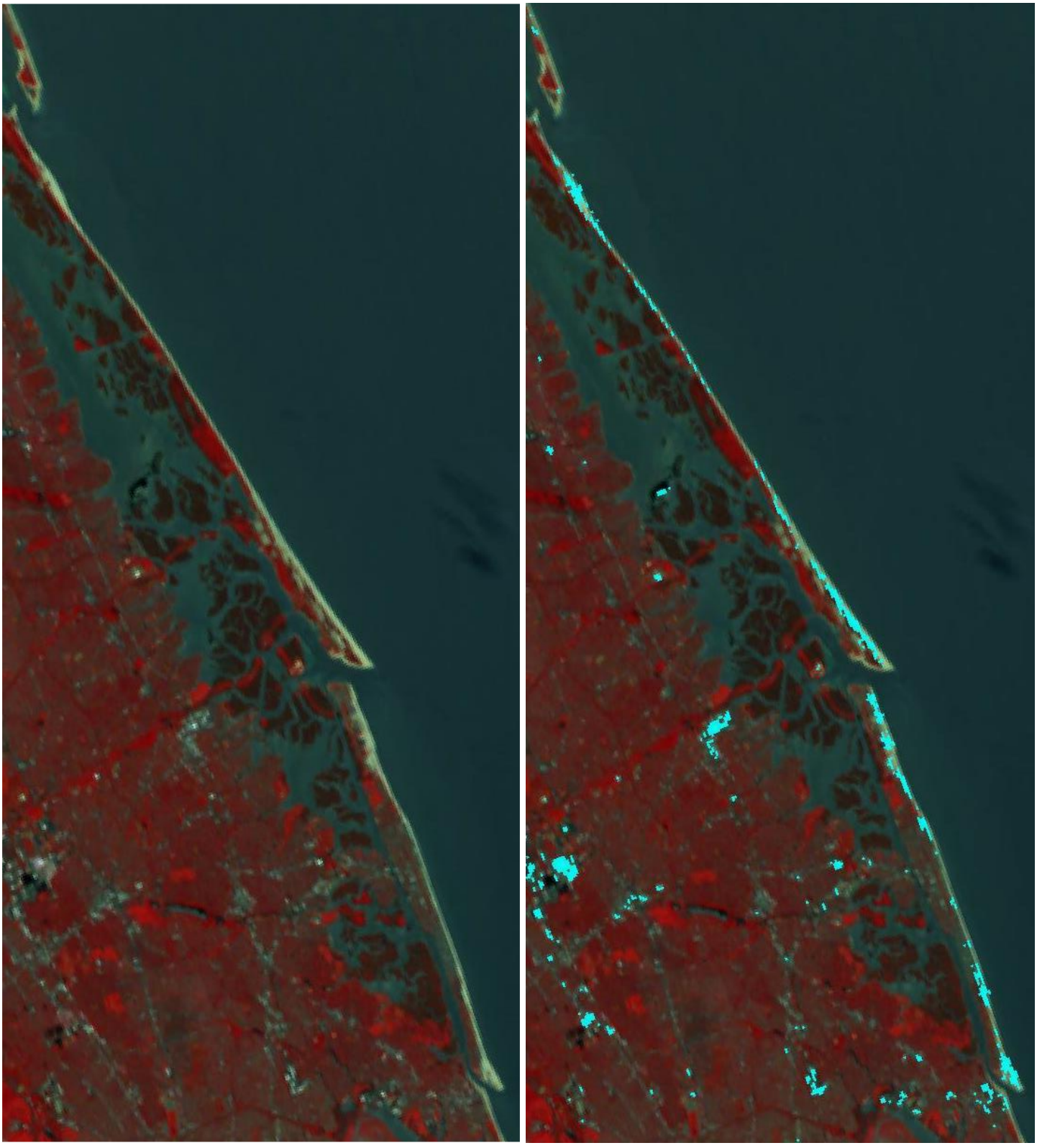
49. PROBAV_S1_TOA_X09Y01_20140621_100M_V101 (Hudson Bay)





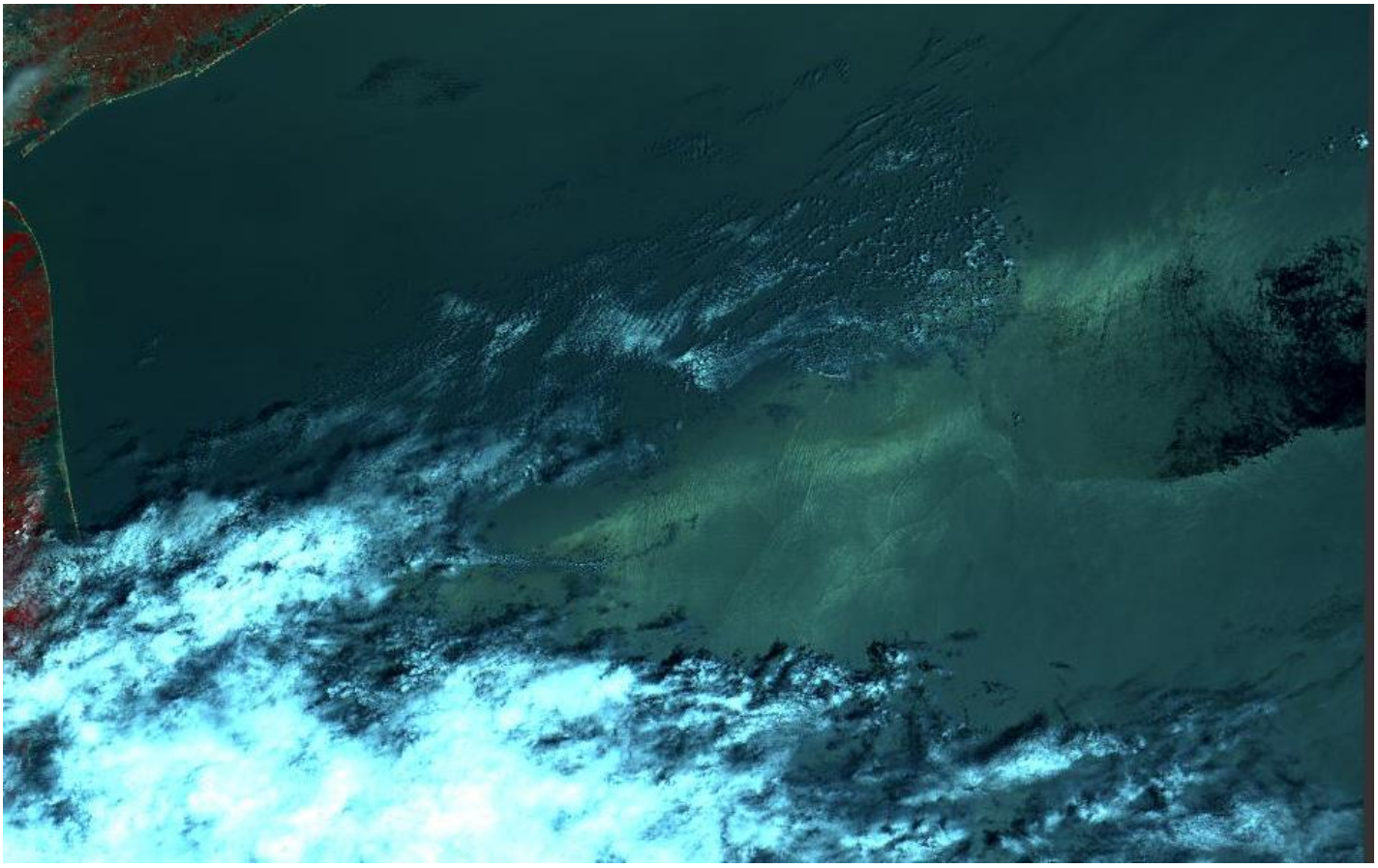
Not all floating sea ice has been recognized.

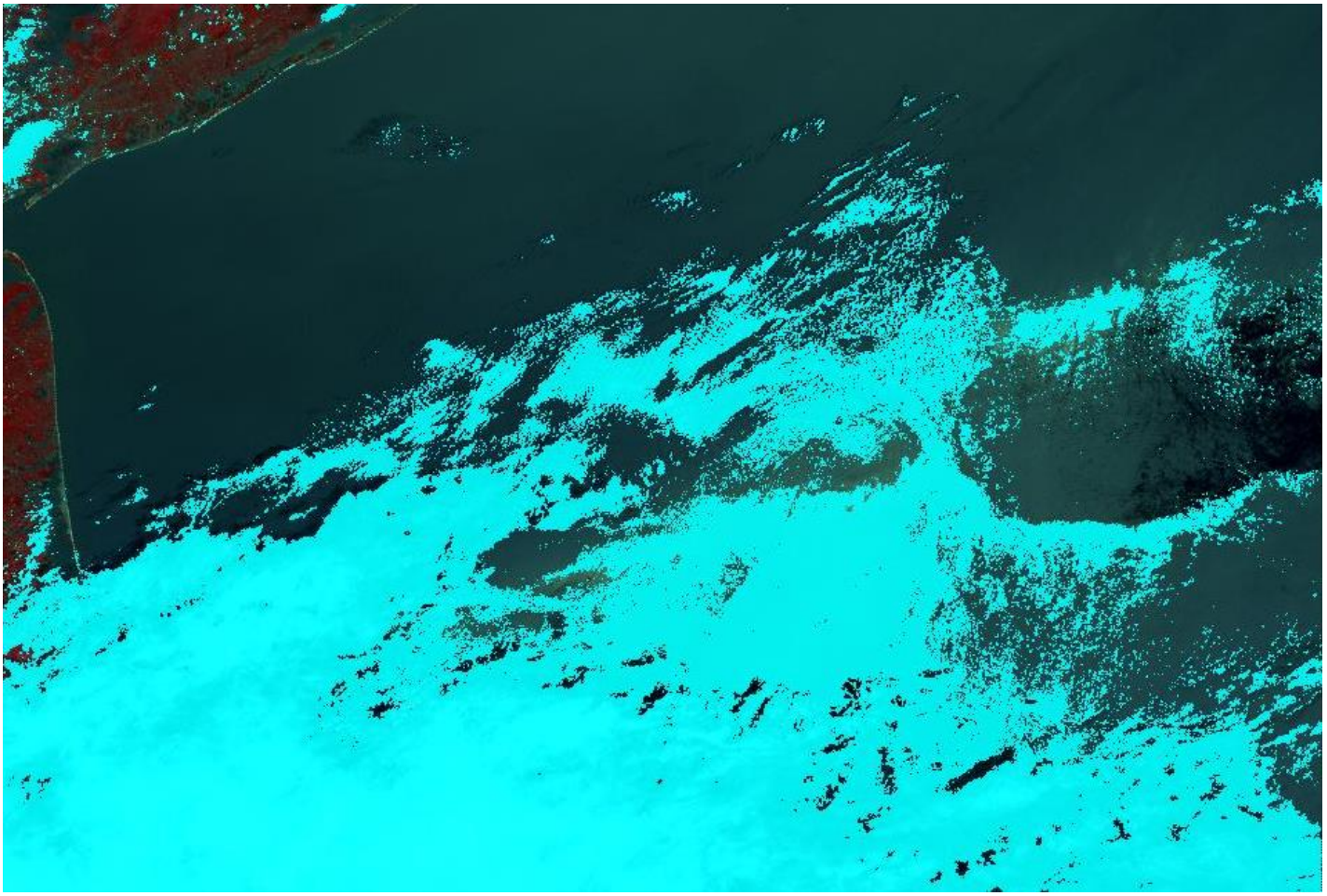
50. PROBAV_S1_TOA_X10Y03_20140621_100M_V101 (Long Beach and other Islands, Long Island, USA)



Sandy coast was incorrectly identified as cloudy.

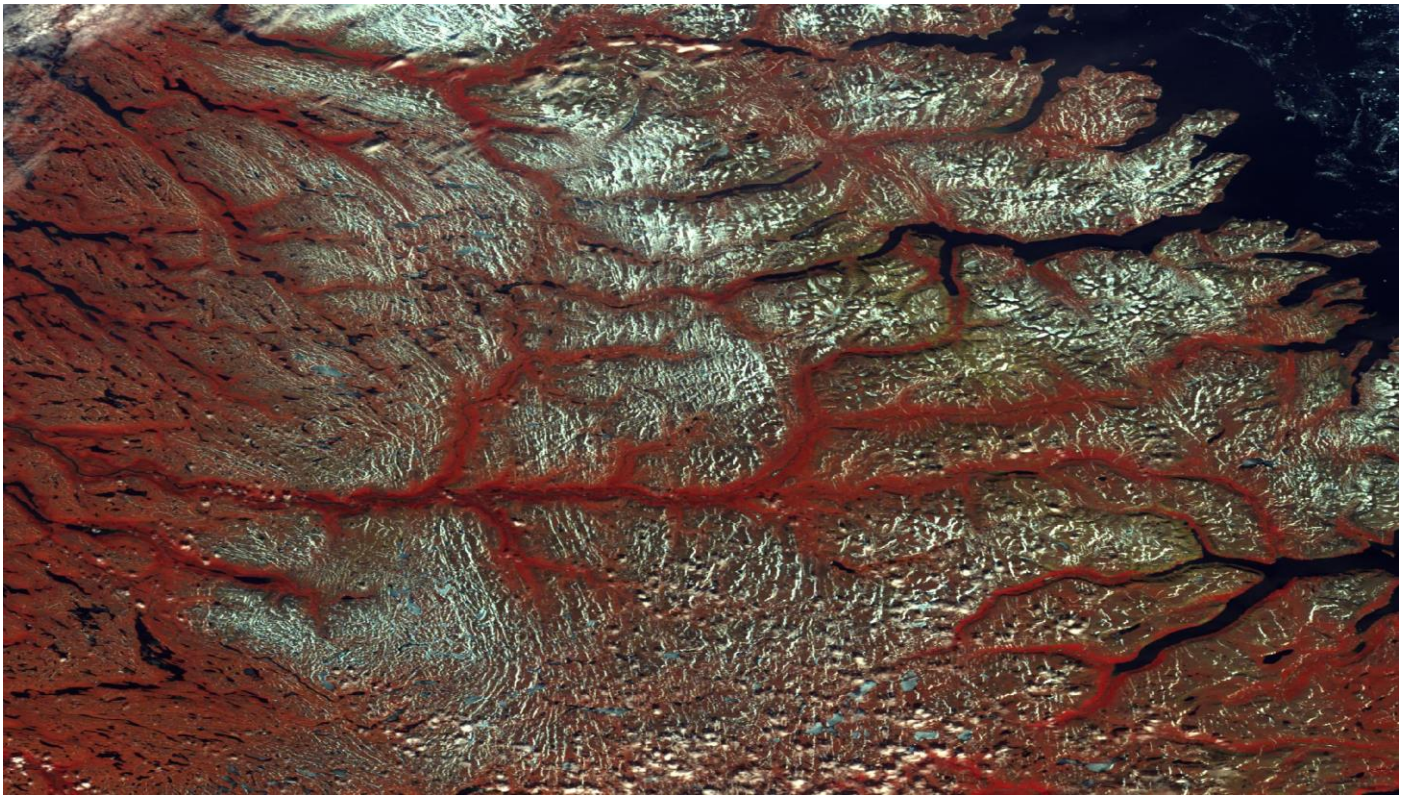
51. PROBAV_S1_TOA_X10Y03_20140621_100M_V101 (Atlantic Ocean in the East of Long Island, USA)

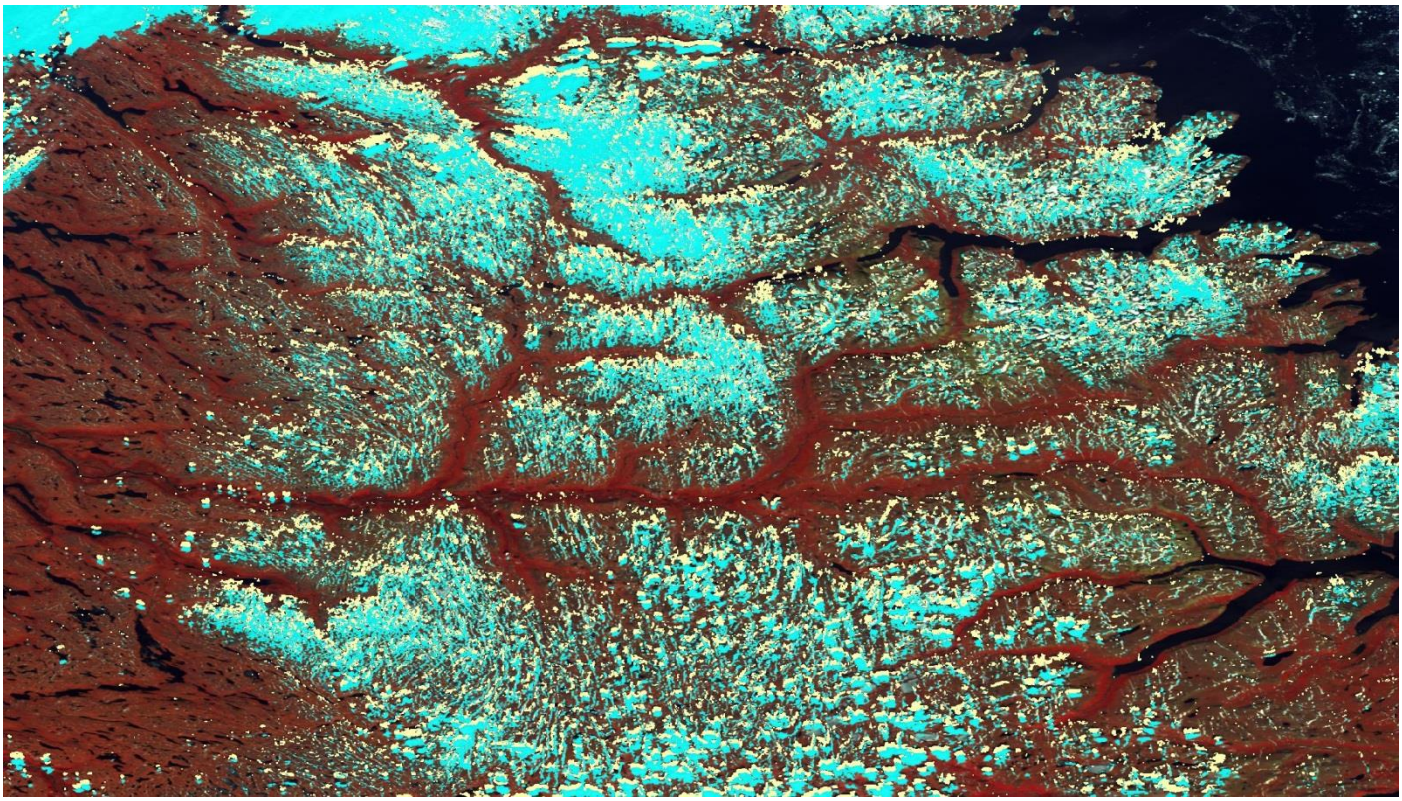




Clear sky sun glint area (on the right) was incorrectly identified as cloudy.

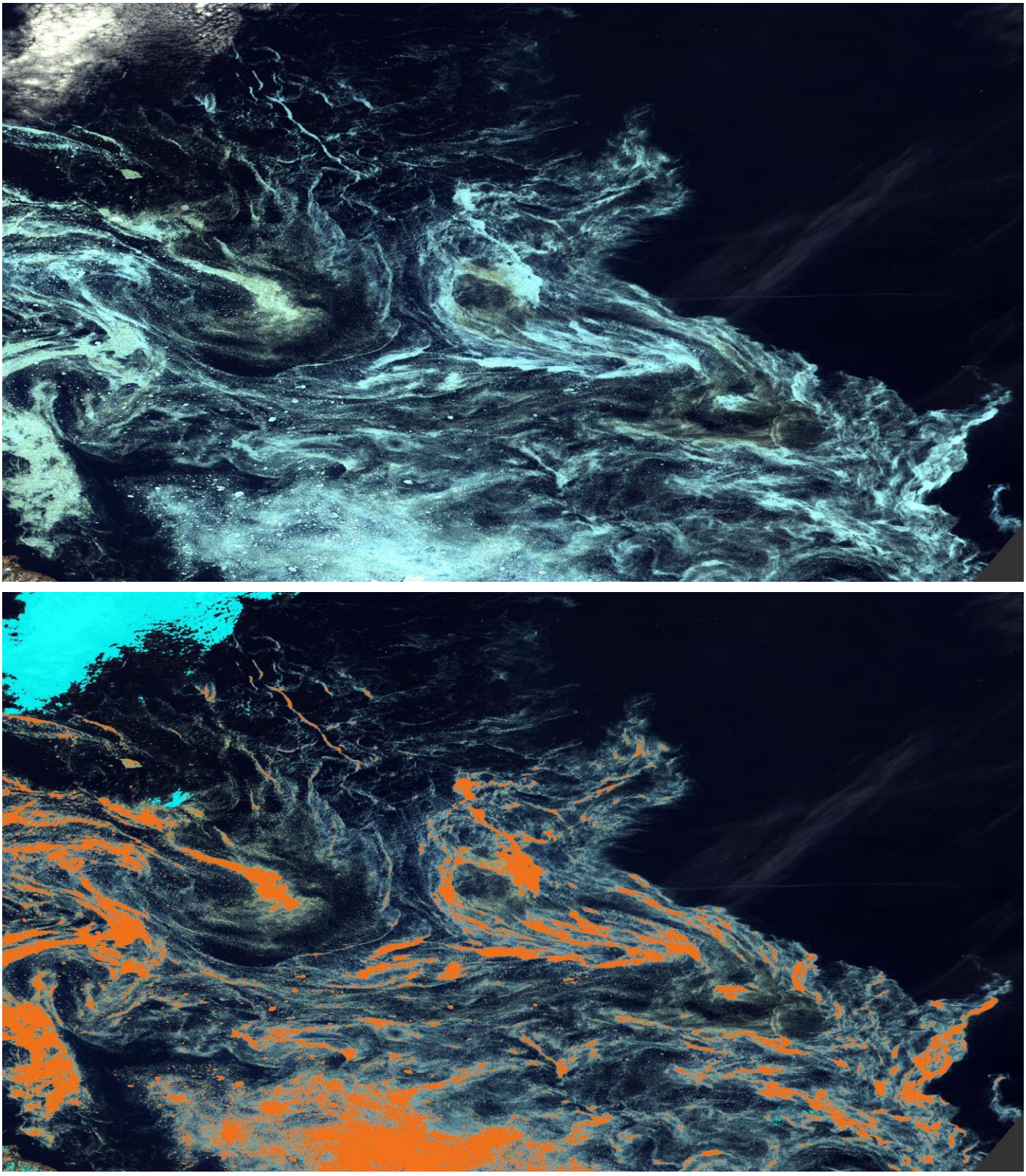
52. PROBAV_S1_TOA_X11Y01_20140621_100M_V101 (Labrador Peninsula)





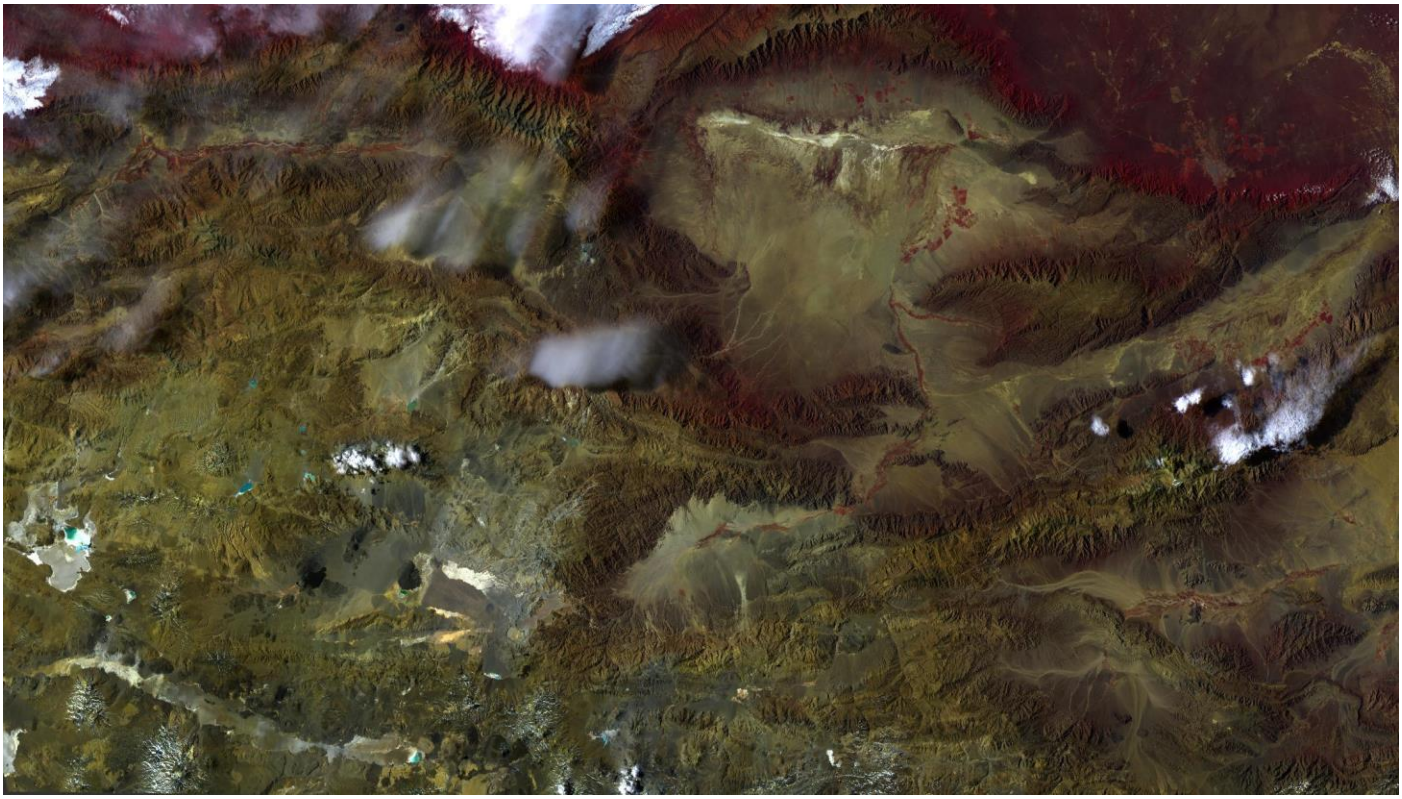
Cloud free areas “partially” covered with snow (probably forests) are mostly incorrectly identified as cloudy. Plus not existing shadow were shown.

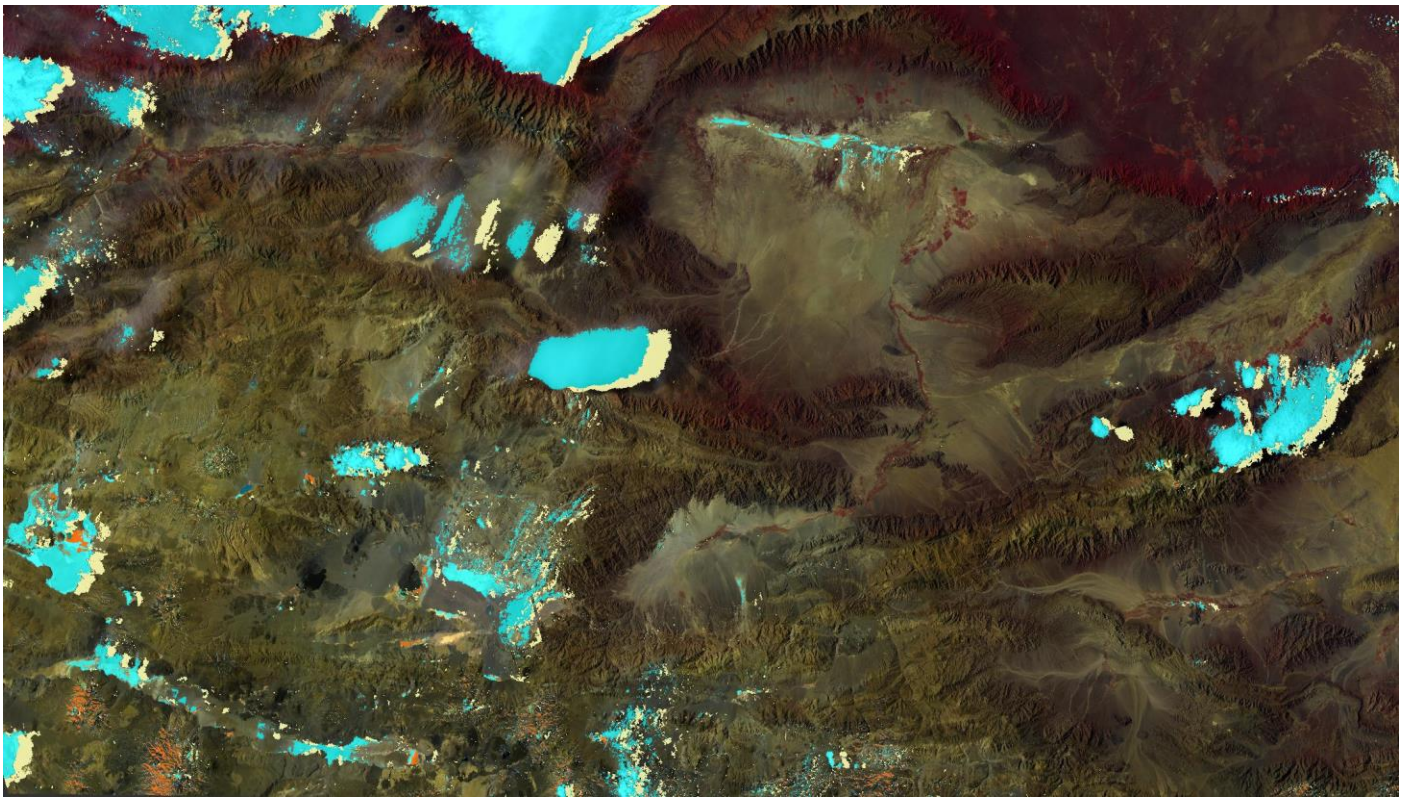
53. PROBAV_S1_TOA_X11Y01_20140621_100M_V101 (Labrador Sea, Hudson Strait)



Many pixels of drifting brash ice have not been recognized.

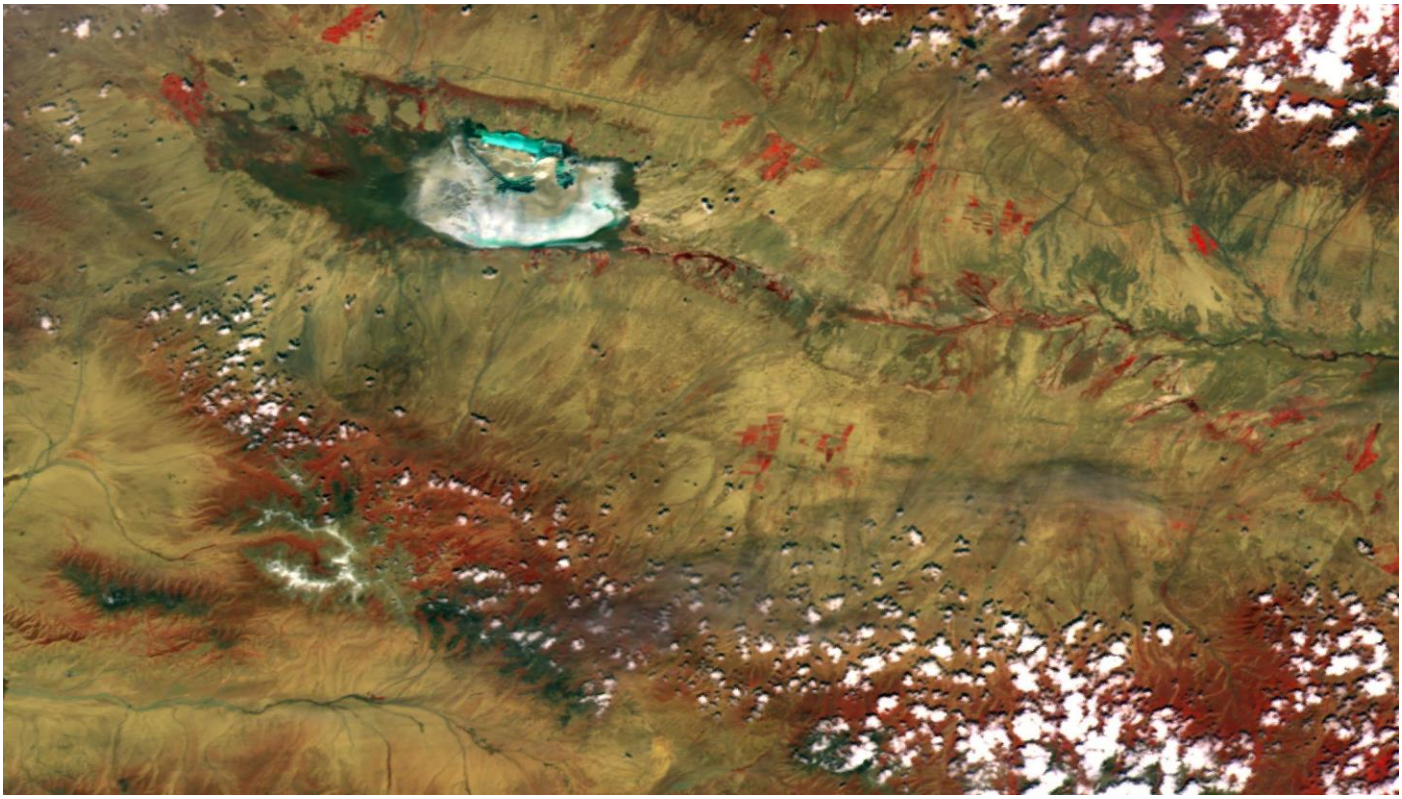
54. PROBAV_S1_TOA_X11Y10_20140621_100M_V101 (Ands, Region de Antofagasta, Chile)

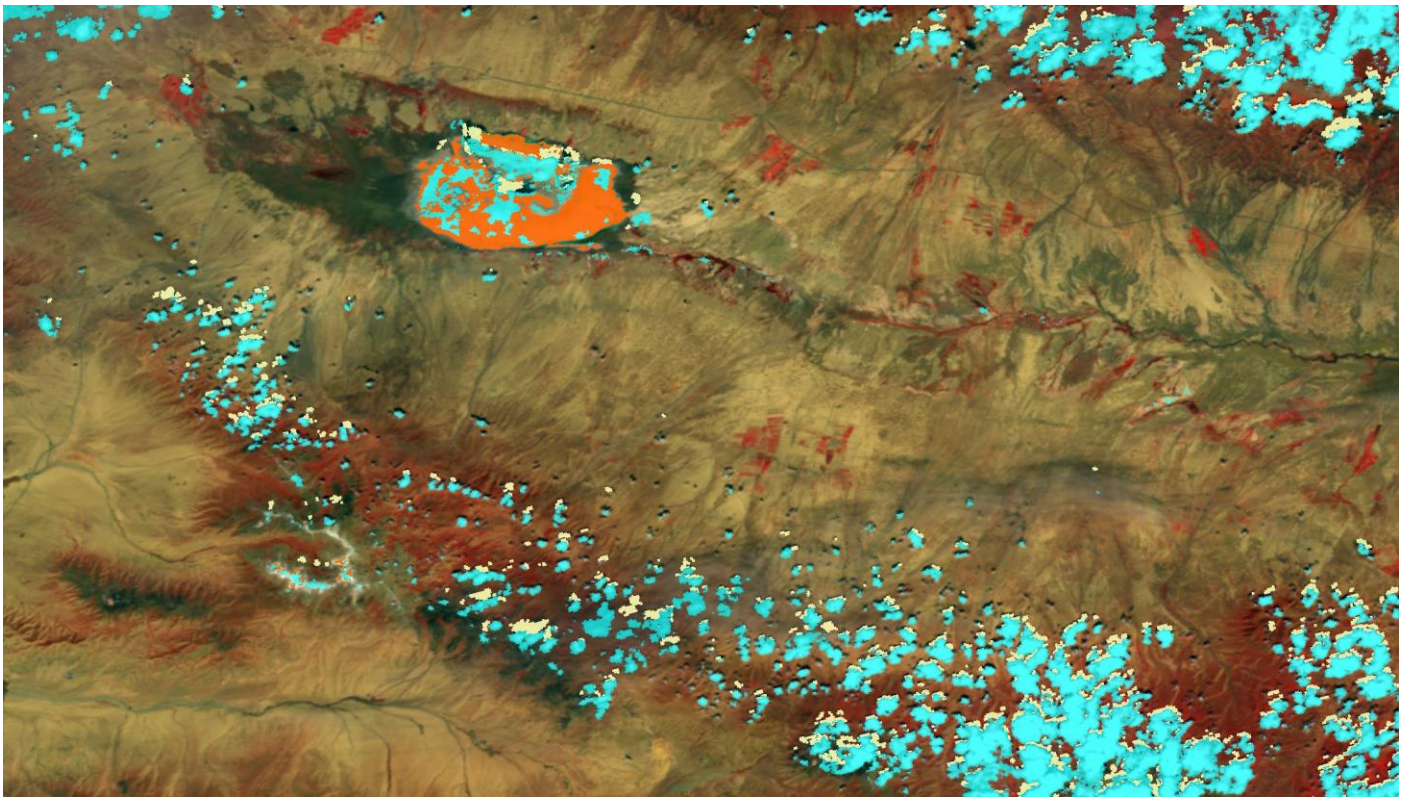




Not only clouds but also salt lakes and dry areas were recognized as cloudy.

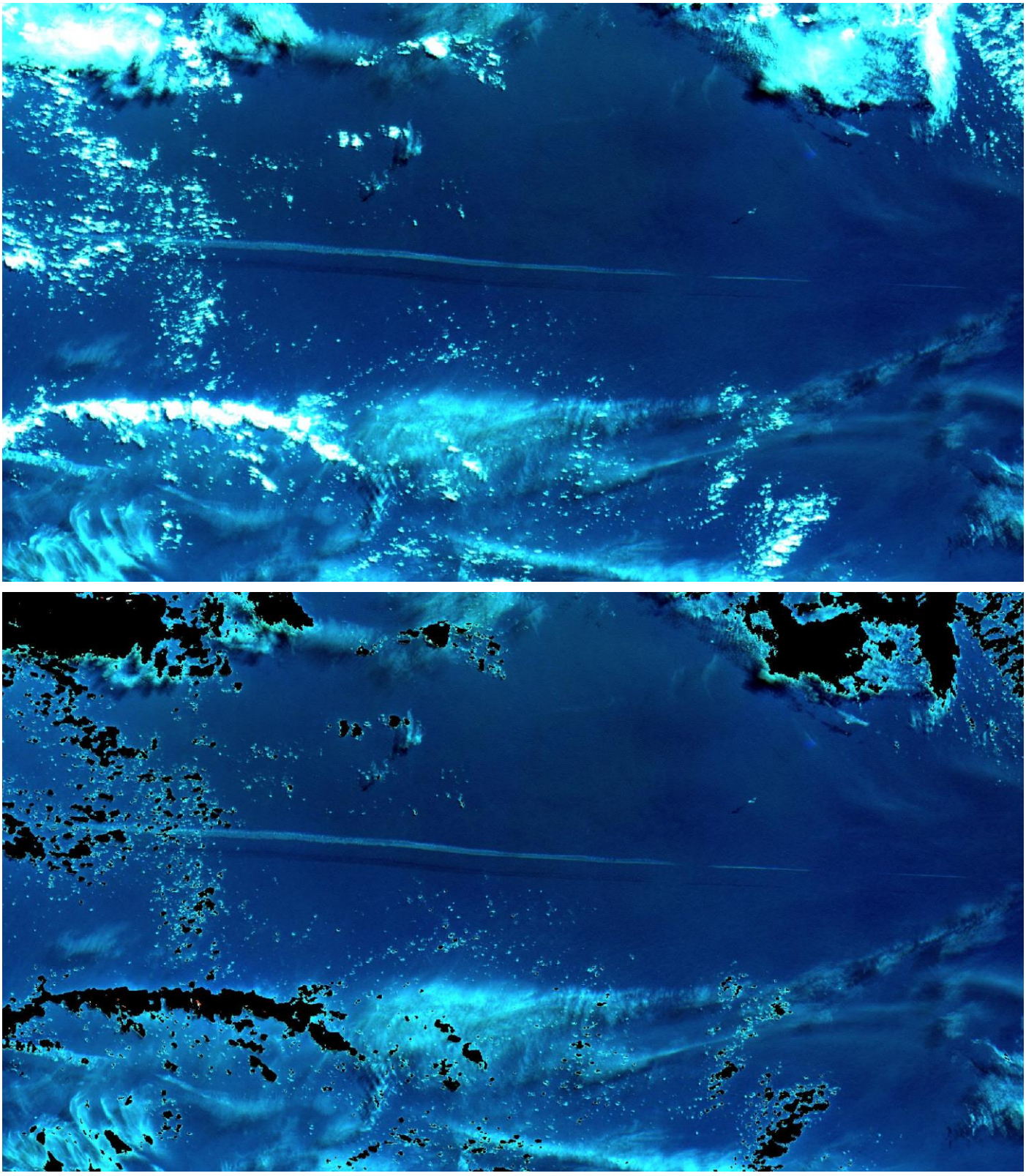
55. PROBAV_S1_TOA_X27Y03_20140621_100M_V101 (Chakayan Lake, Province Qinghai, Central China)





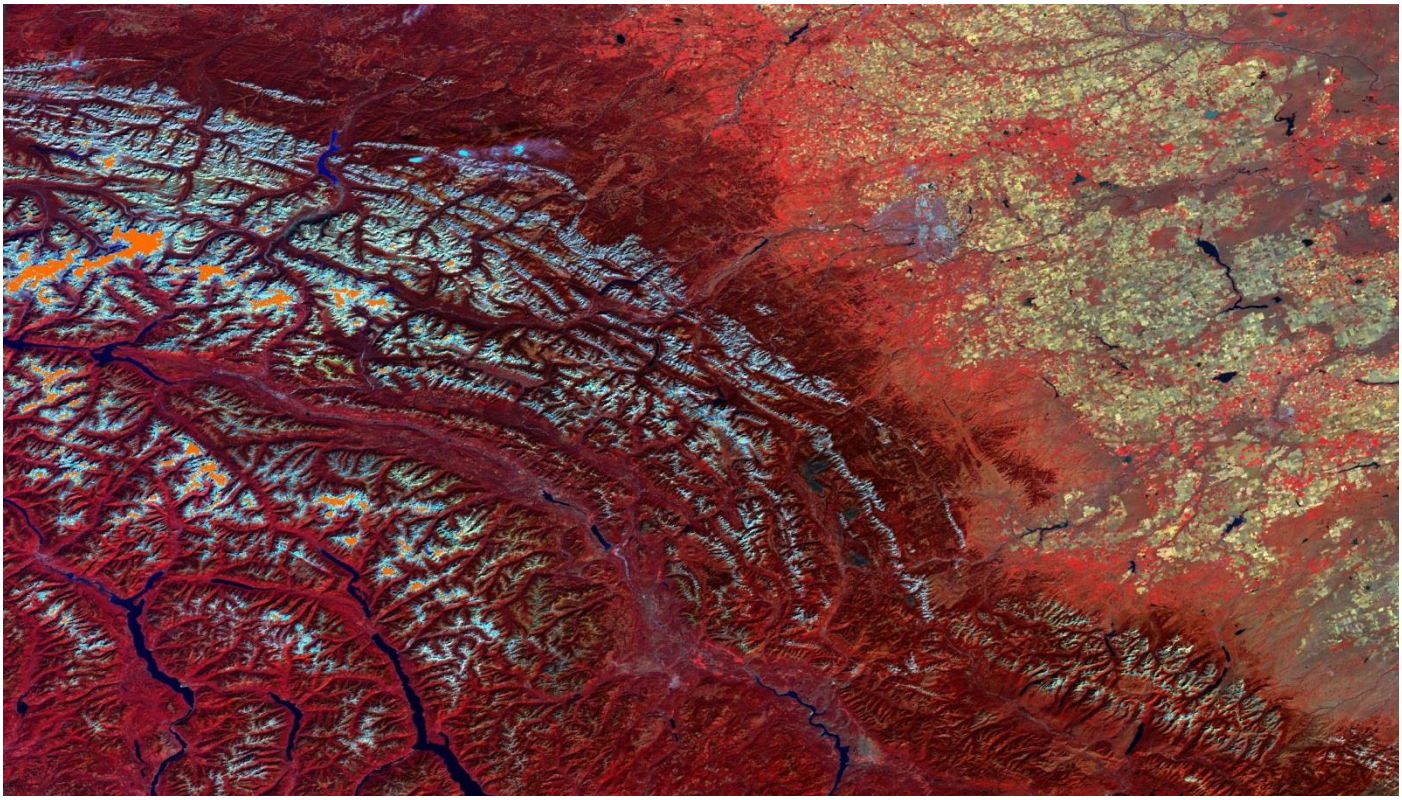
Salt or/and dry lake pixels were recognized as cloudy or icy. It is difficult to determine when which mask was displayed incorrectly.

56. PROBAV_S1_TOA_X27Y07_20140621_100M_V101 (Indian Ocean in the West of Sumatra)



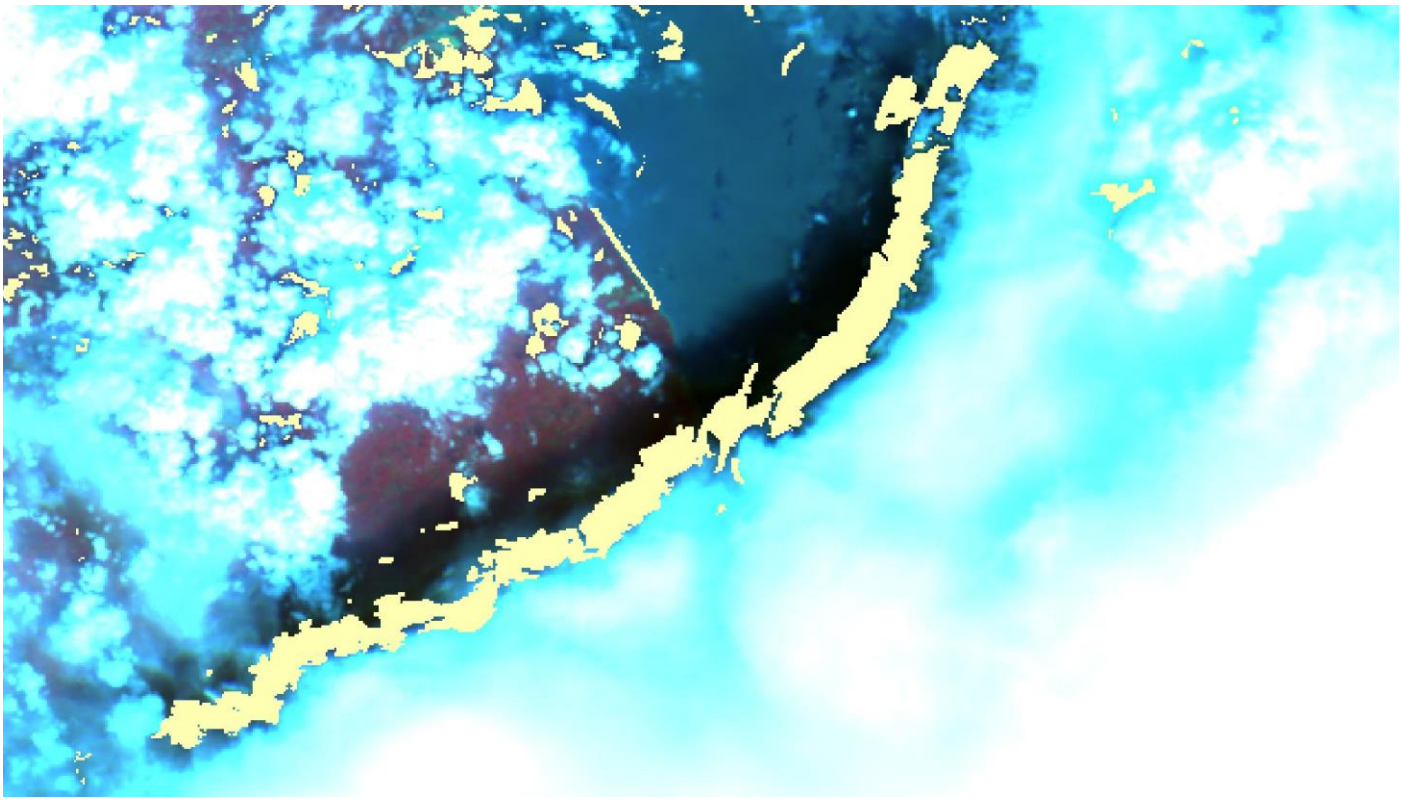
The semi-transparent clouds are quite imperceptible in this picture (if not contrasting), but well present. The cloud mask (black) does not show it.

57. PROBAV_S1_TOA_X06Y02_20140921_100M_V101 (Columbia Mountains, West Canada)



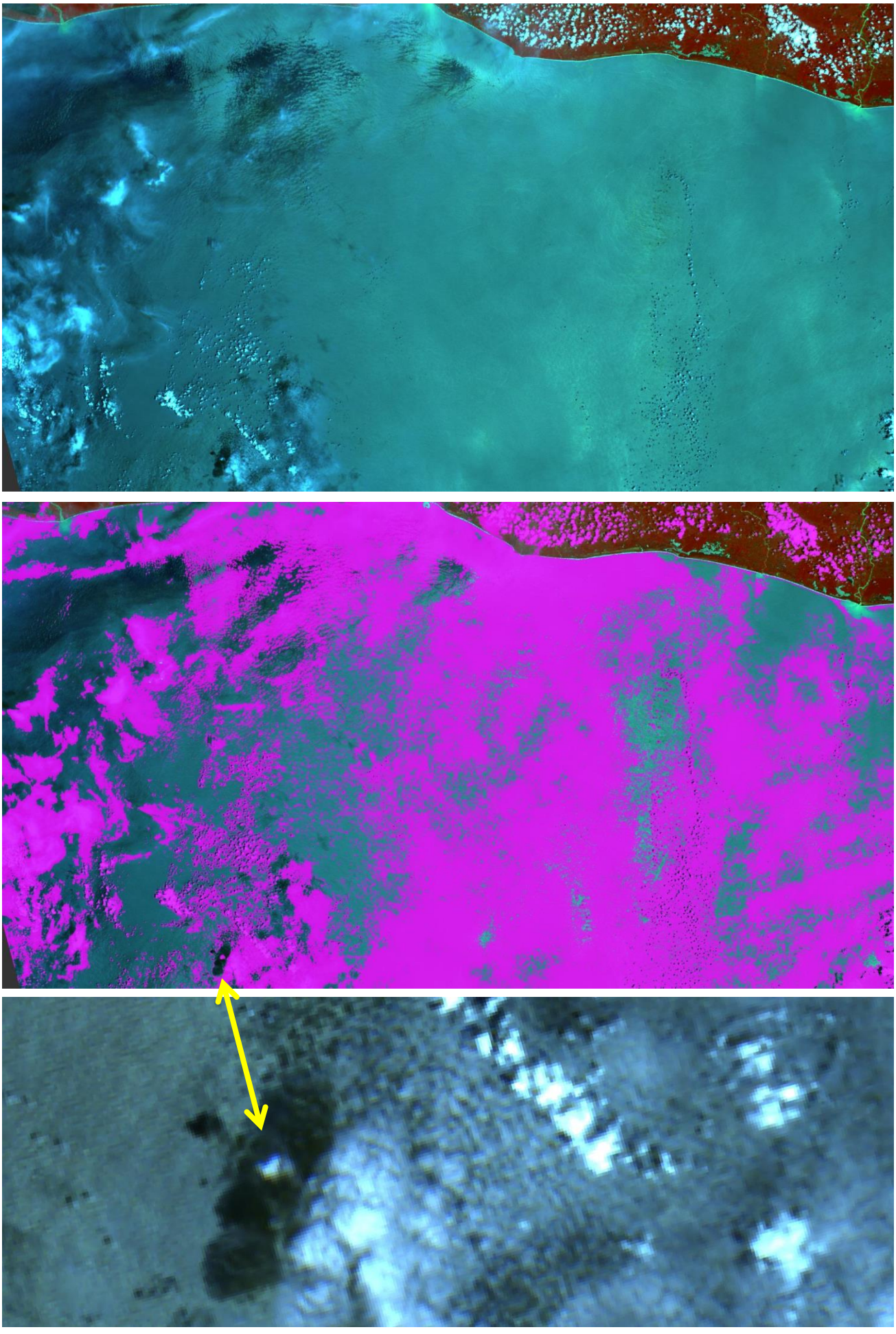
Several clearly recognizable snow pixels (the picture is not contrasted) were not marked as such.

58. PROBAV_S1_TOA_X08Y05_20140921_100M_V101 (Panama)



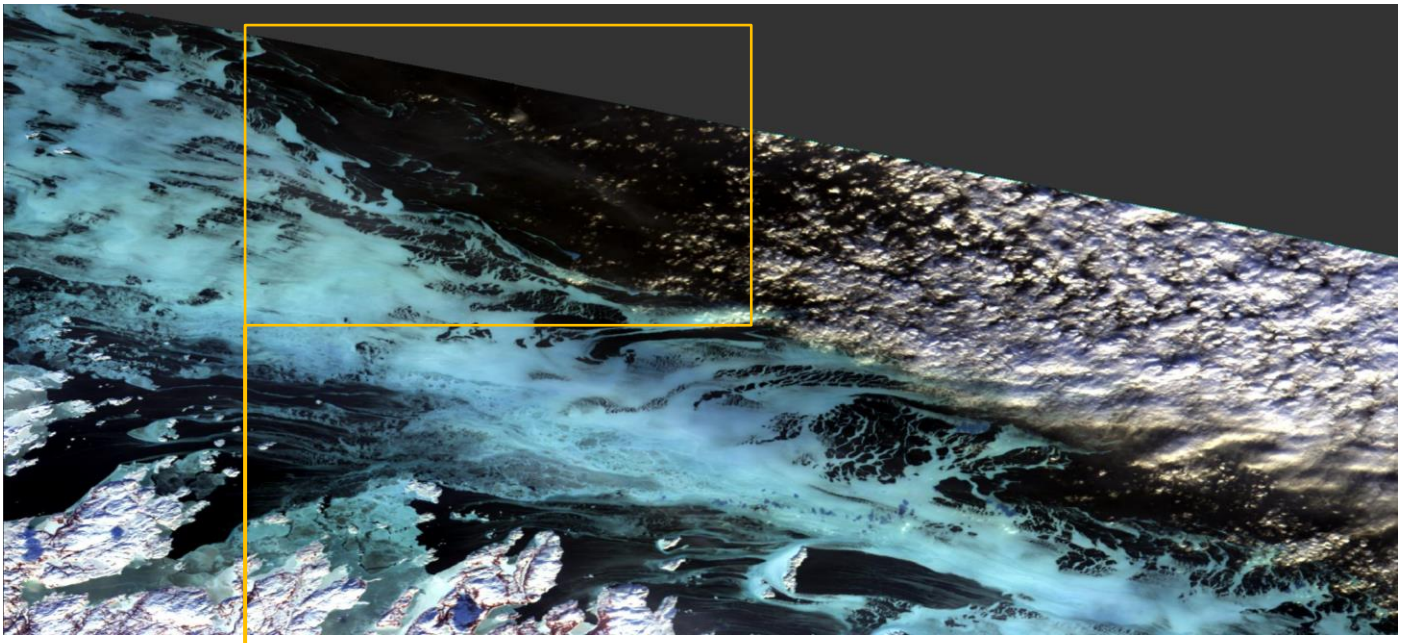
Cloud height was not correctly estimated (in reality they are about 2-3 times higher), so the cloud shadows are too short.

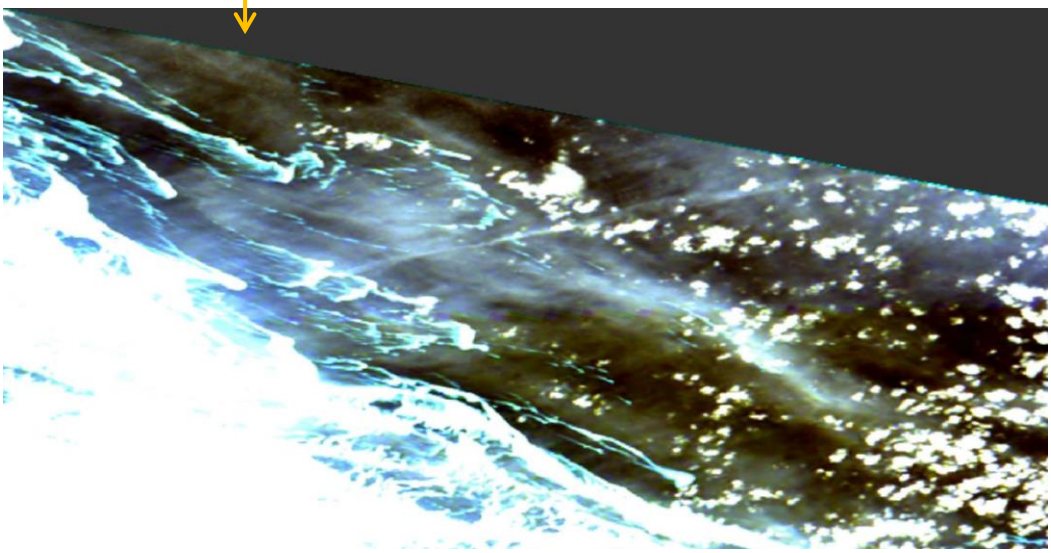
59. PROBAV_S1_TOA_X08Y05_20140921_100M_V101 (Pacific in the south of Panama)



A numerous of sun glint pixels were incorrectly identified as cloudy. Clearly recognizable shadows were not masked (yellow arrow).

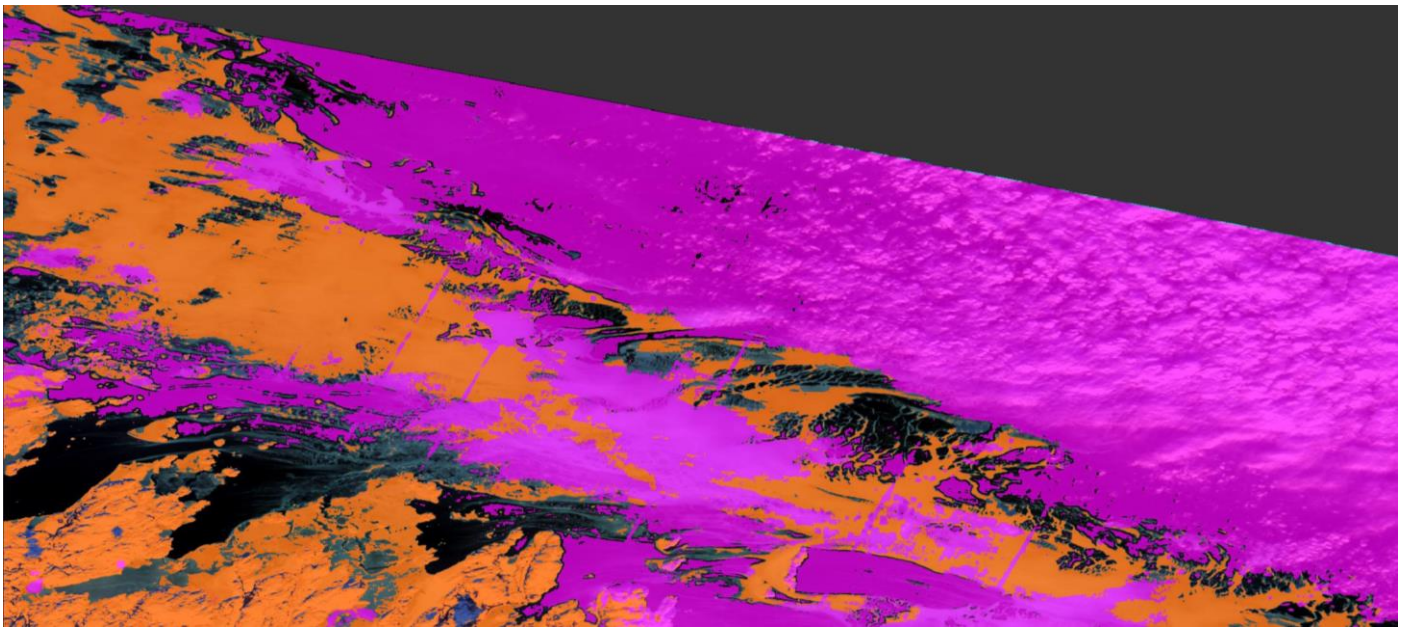
60. PROBAV_S1_TOA_X12Y01_20141221_100M_V101 (Davis Strait in the west of Greenland)



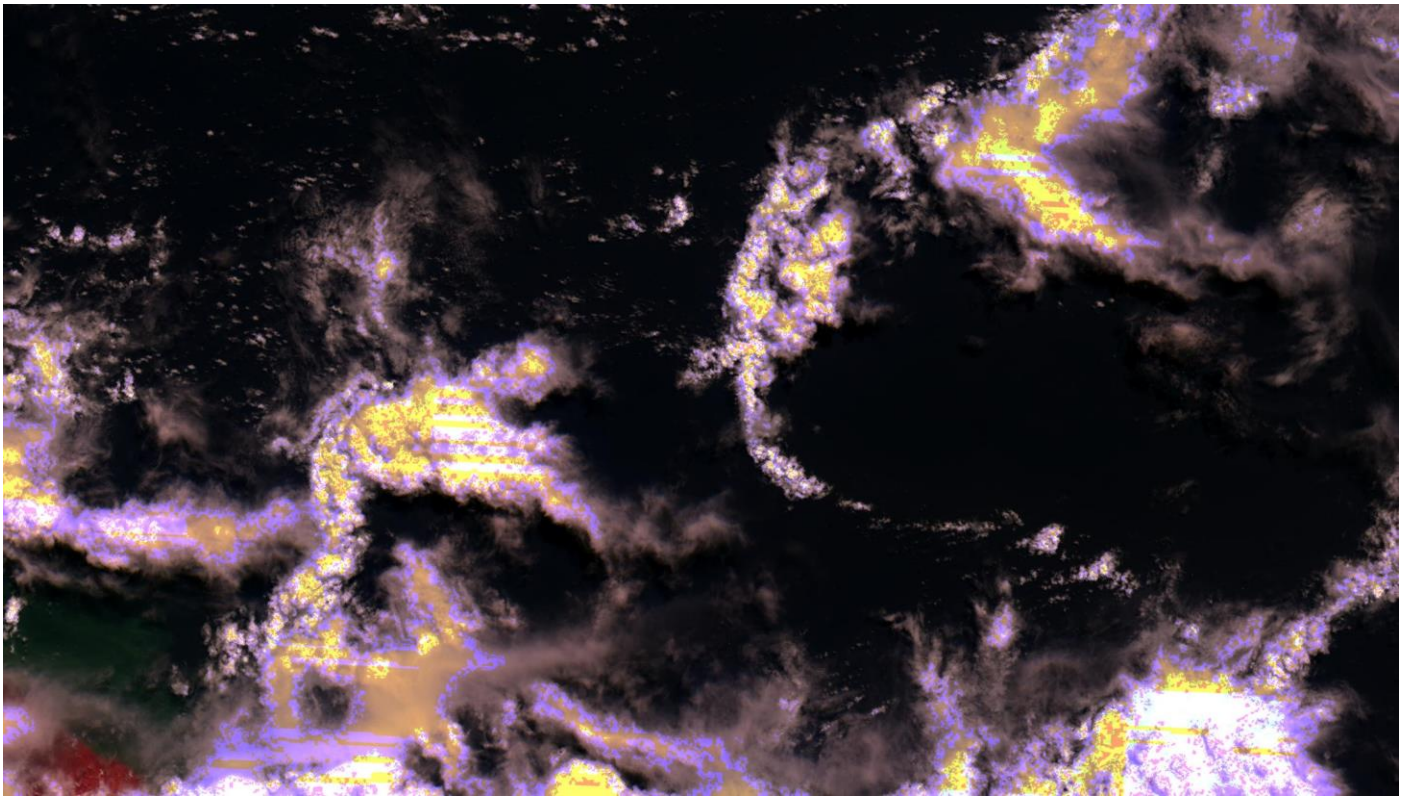


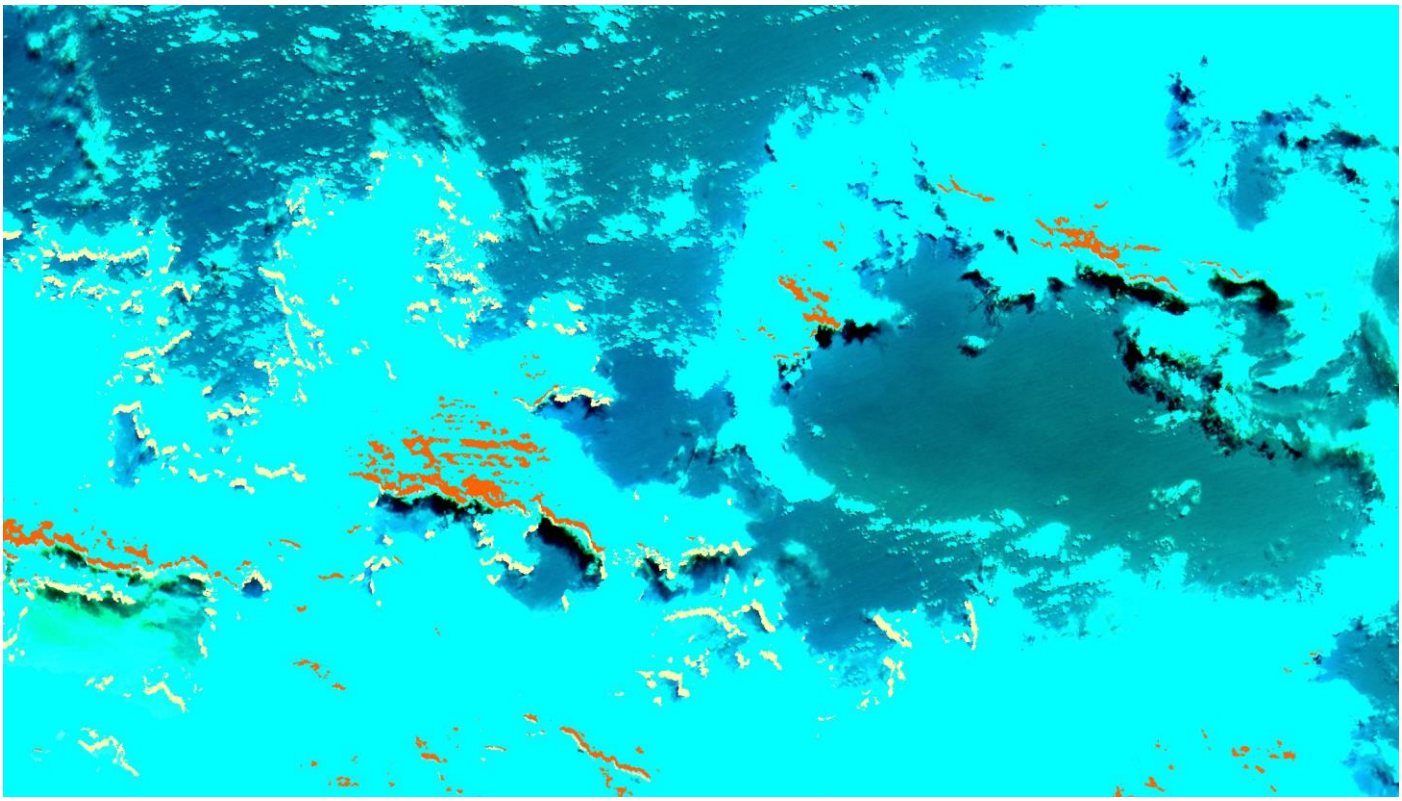
Semi-transparent clouds are hardly visible in the yellow rectangle (picture above). However if this area will be contrasted, many clouds can be seen there.
Nevertheless, the entire cloud- and ice mask looks too chaotic and not always correct.

This file is well suited to adjust the method.



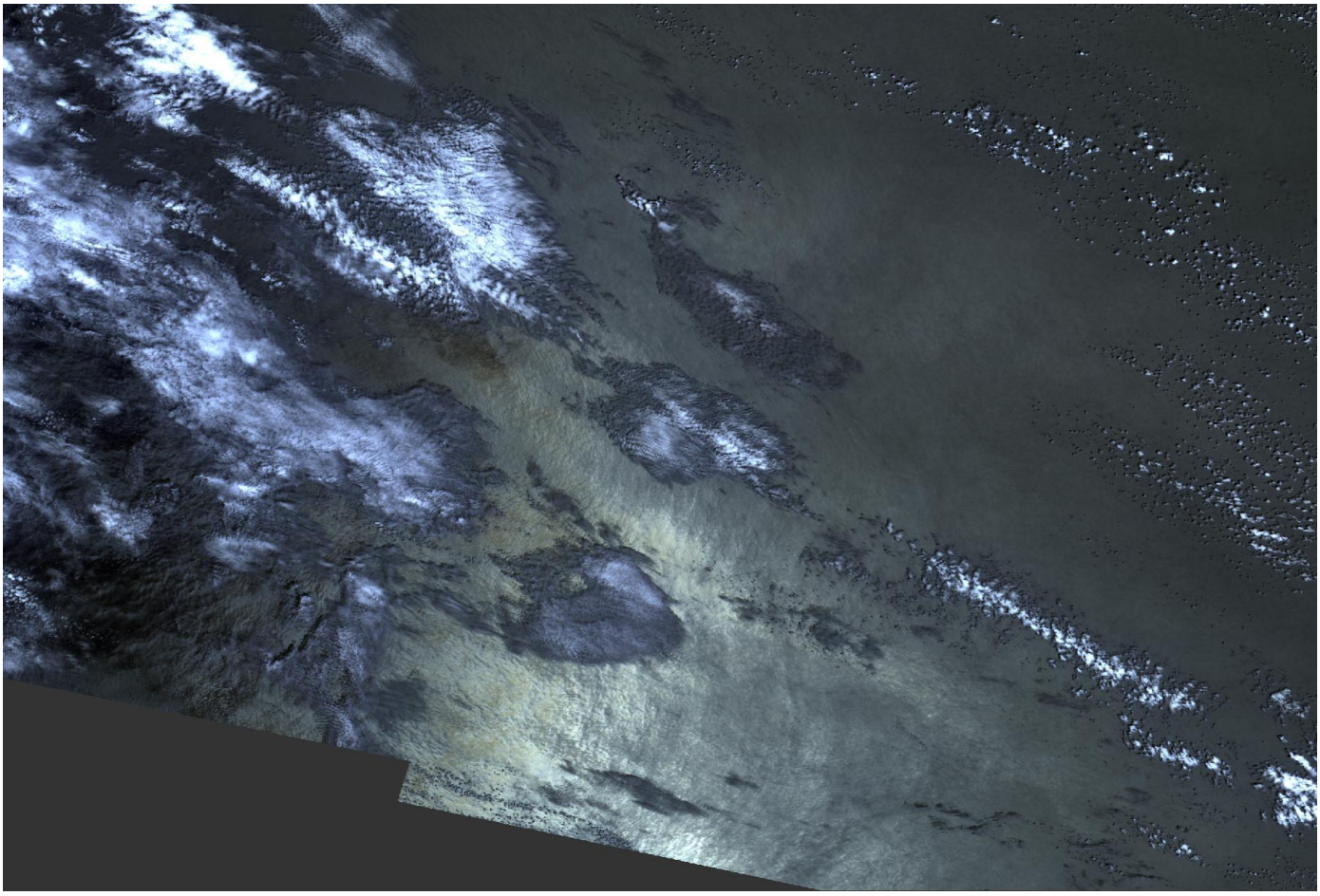
61. PROBAV_S1_TOA_X12Y06_20140621_100M_V101 (Atlantic Ocean in the North of Suriname)

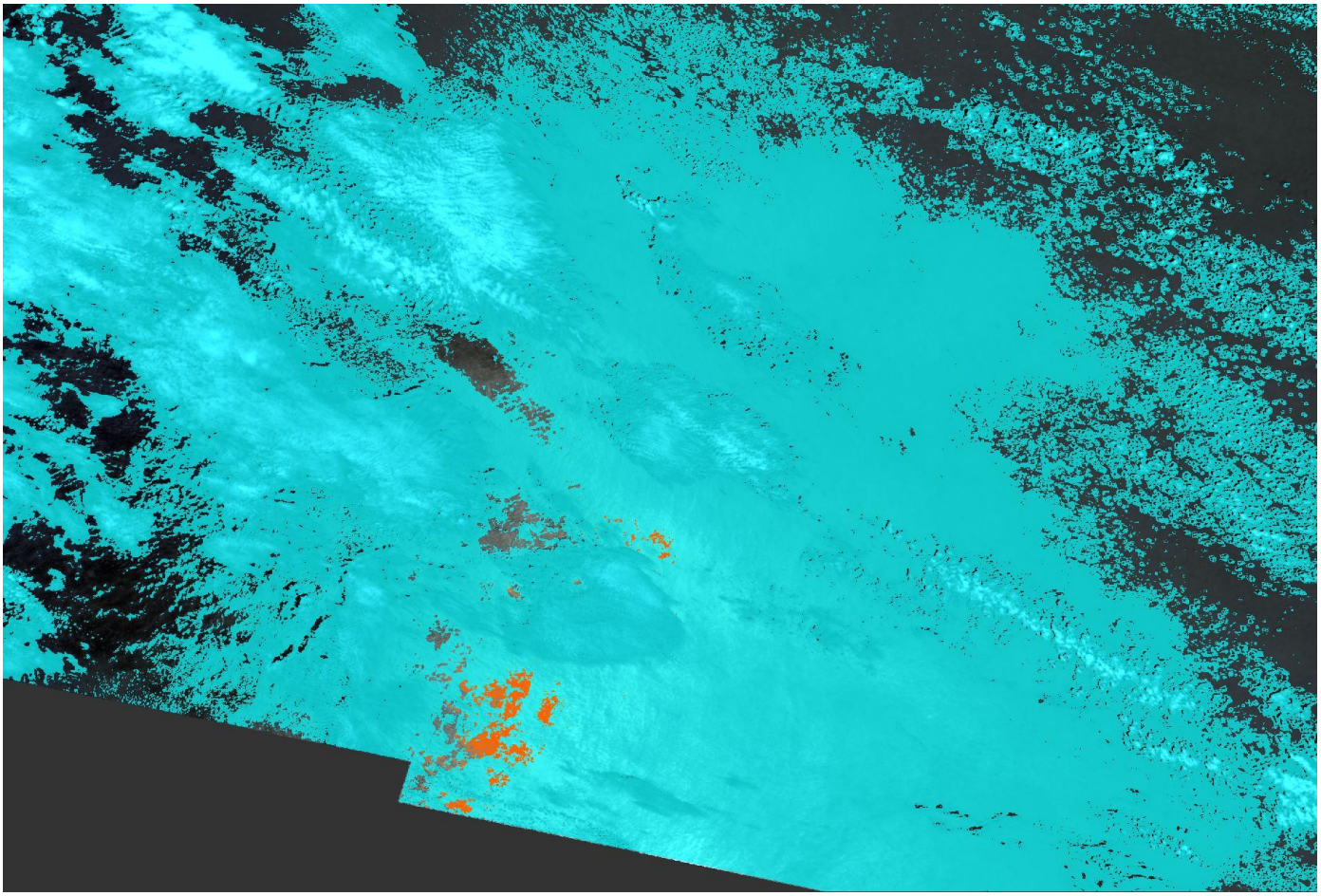




A lot of cloud pixels are preliminarily already marked. These are results of "quality flagging" in one or more satellite channels. This flagging complicates the visual recognition of regions and individual pixels by both experts and the computer-automated method. This also means that all pixels starting from some brightness are not only marked as "NOT GOOD", but are "flattened" with a fixed value. Consequently the structure of objects (clouds, mountains, etc.) can no longer be recognized, i.e. define correctly.
The two pictures above illustrate this statement in a certain way. Some cloud pixels were masked as snow. Some shadows are wrong, from another ones are missing any trace.

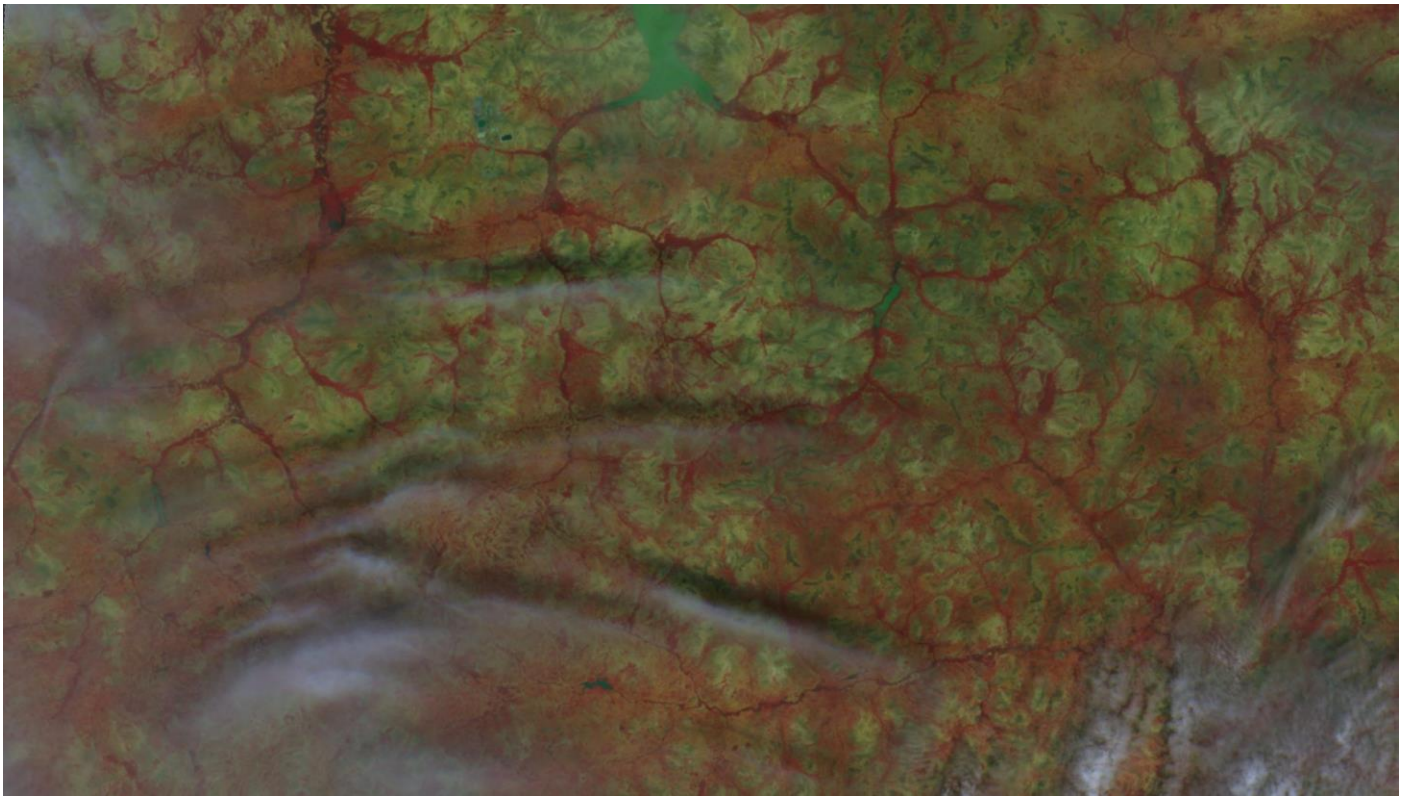
62. PROBAV_S1_TOA_X15Y03_20140621_100M_V101 (Azores, Atlantic Ocean)

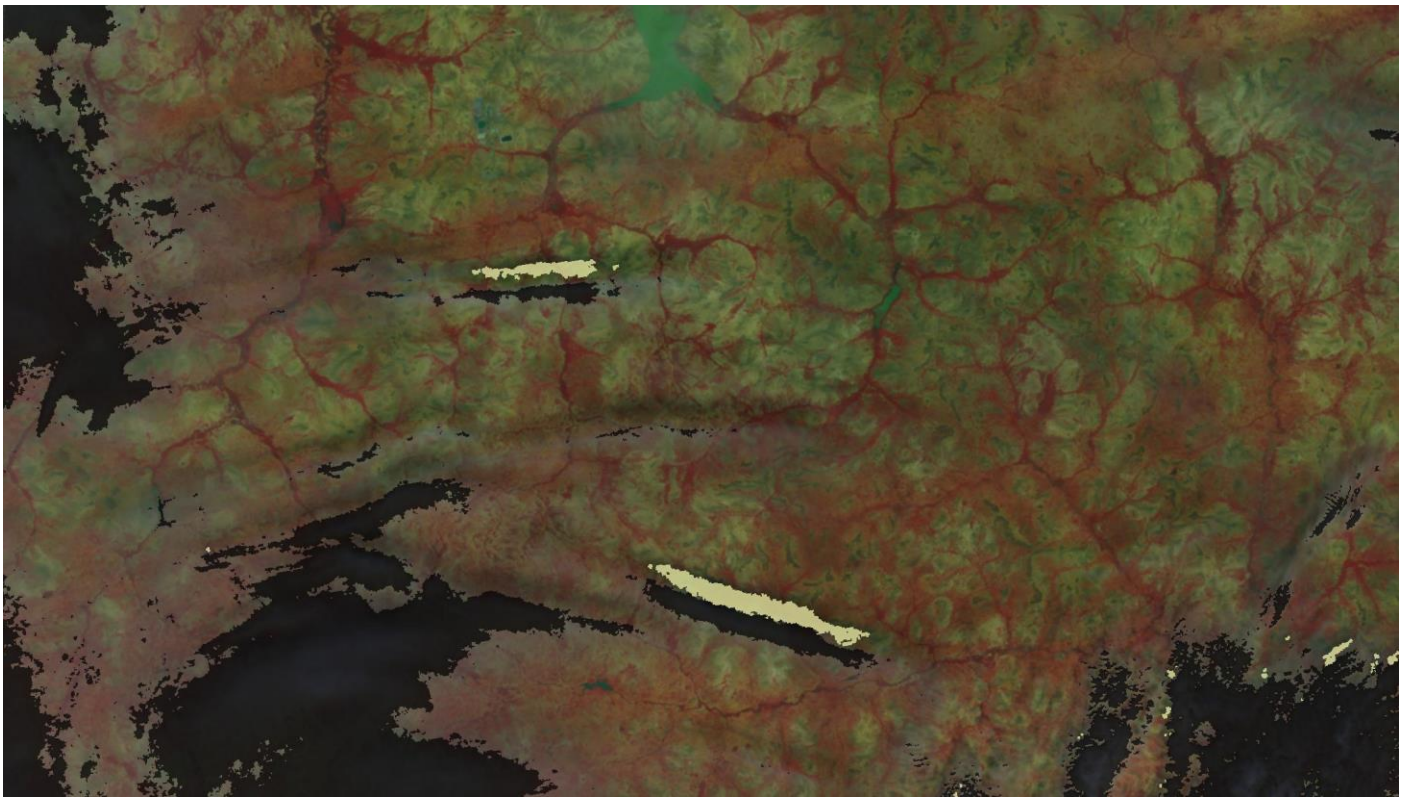




Sun glint pixels were wrong masked as cloudy (and even ice!).

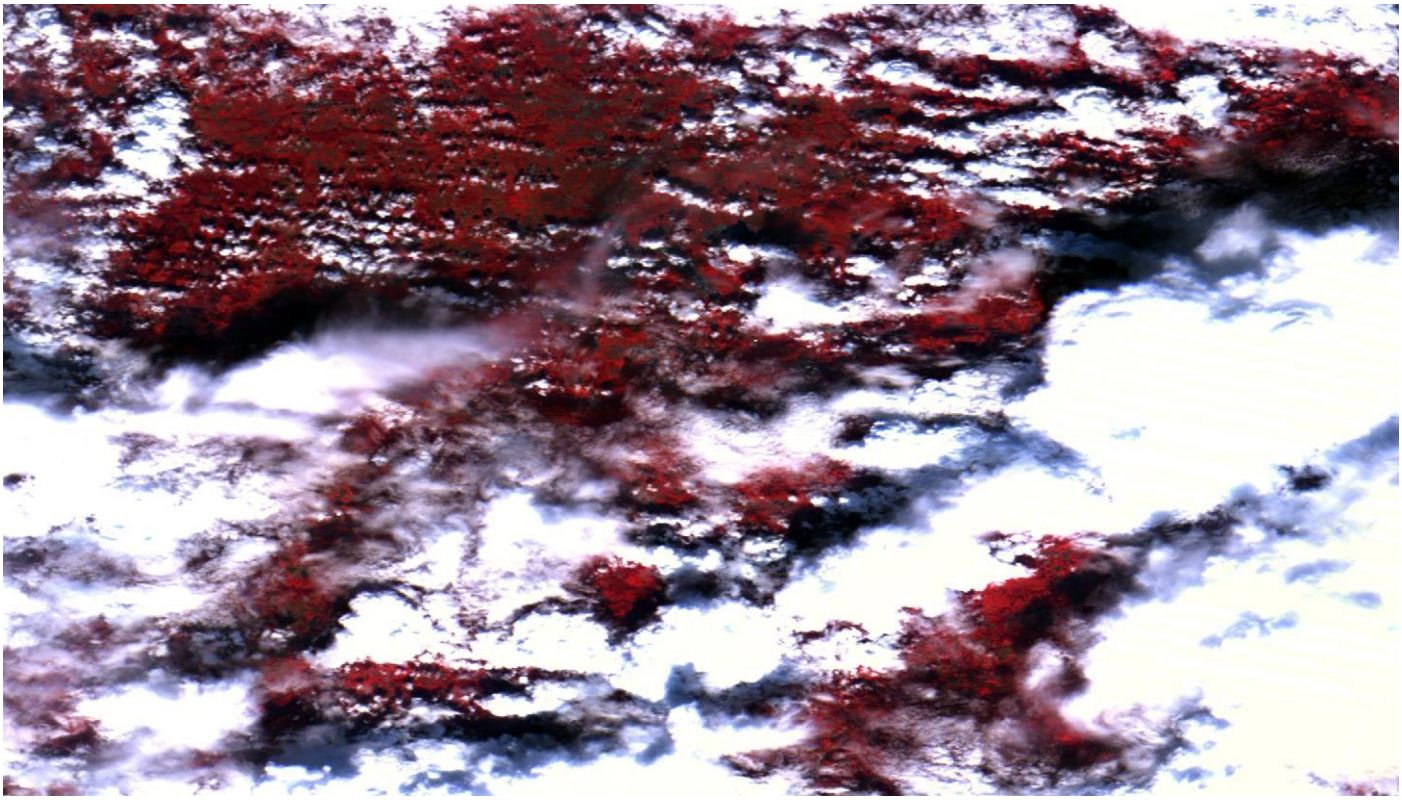
63. PROBAV_S1_TOA_X17Y06_20140921_100M_V101 (West Africa, Côte d'Ivoire)

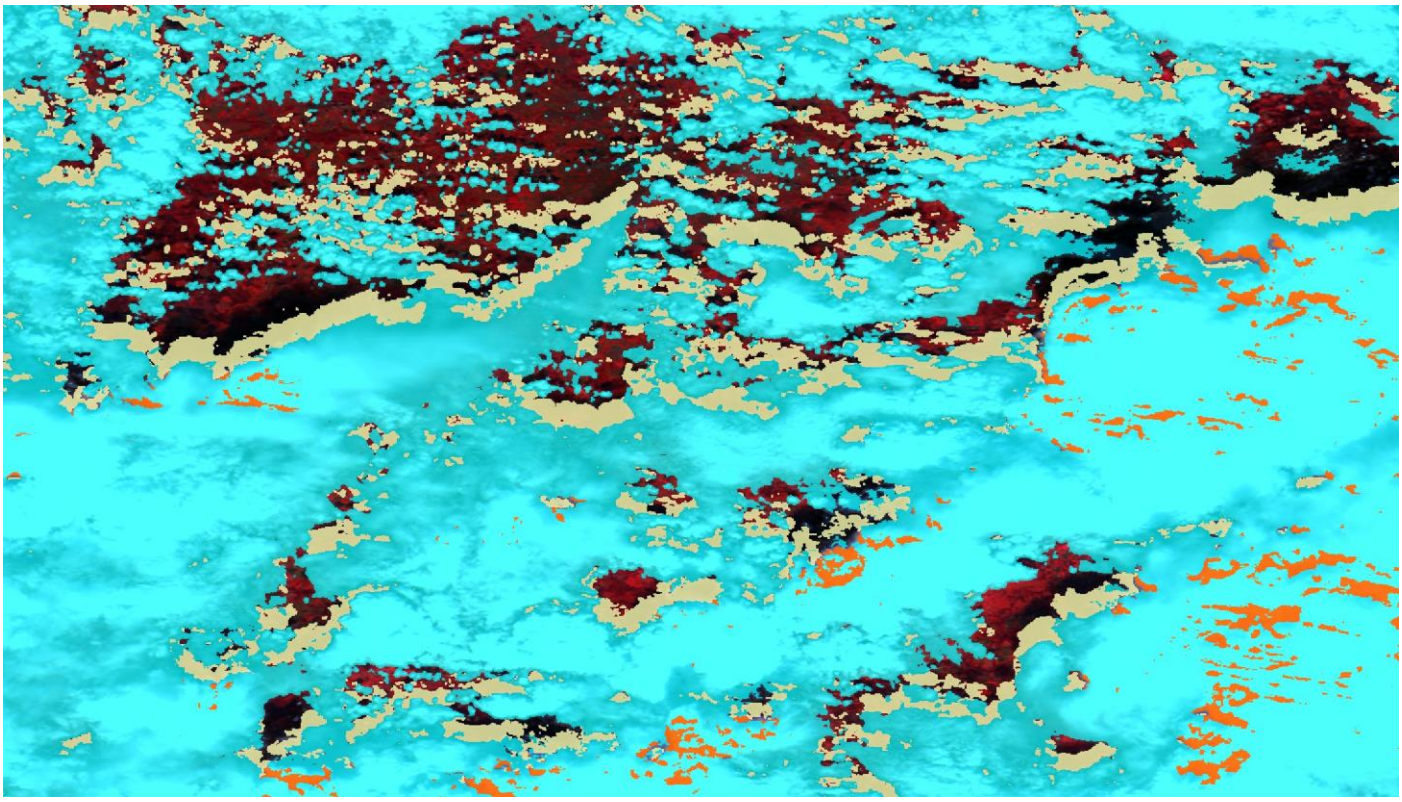




Though pretty good cloud (marked in black) and shadow mask, but not everything was found.

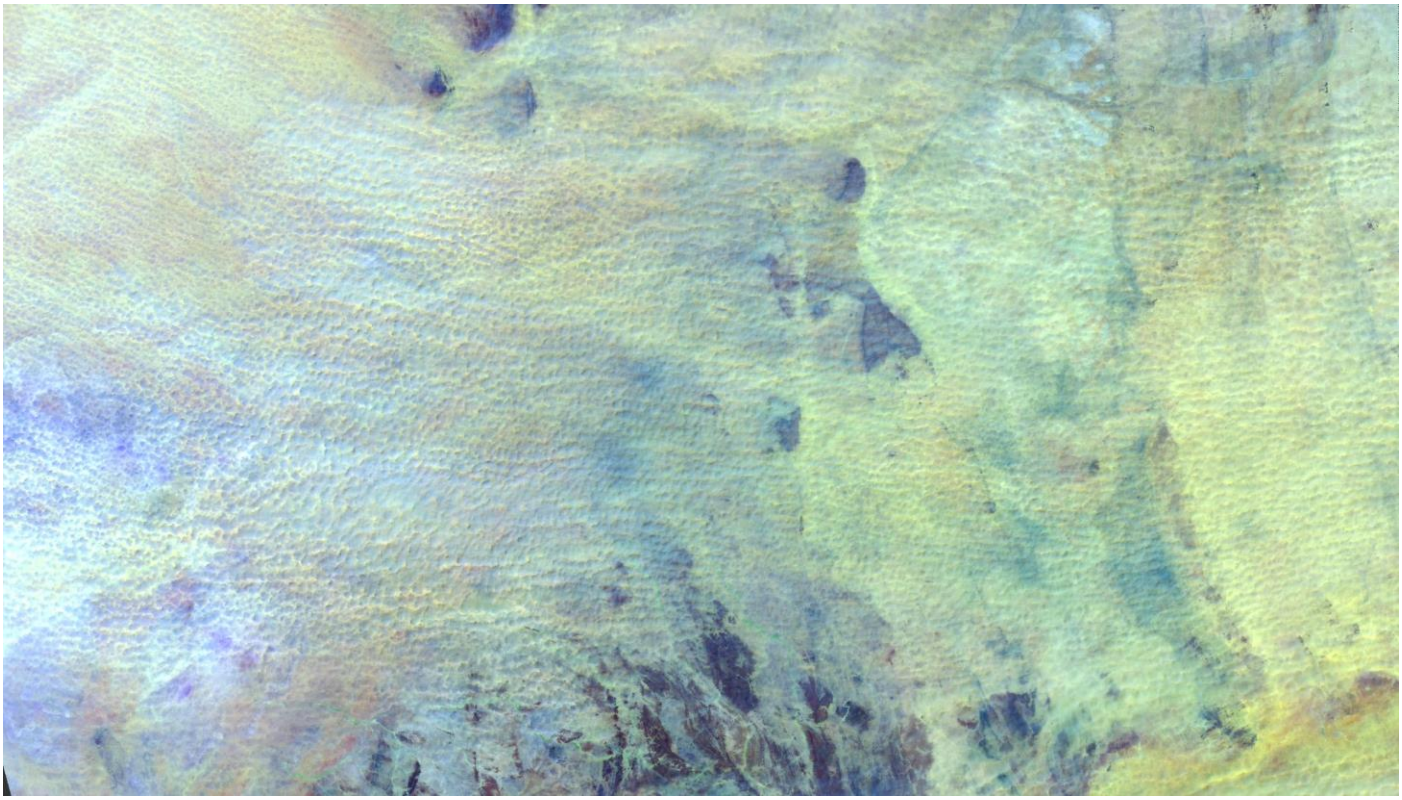
64. PROBAV_S1_TOA_X18Y02_20140921_100M_V101 (France)

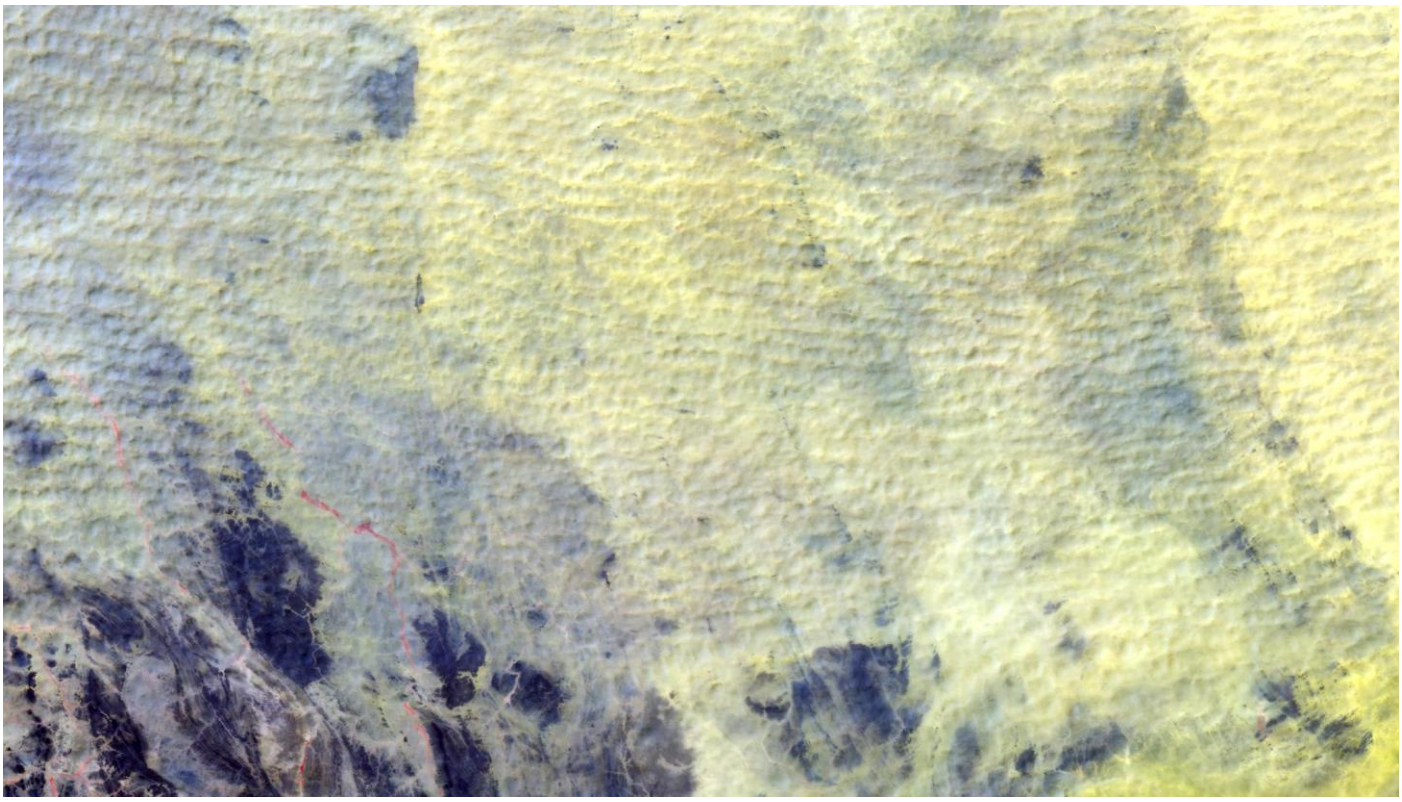




The length of the shadow was not determined correctly. That means cloud height estimation is wrong.

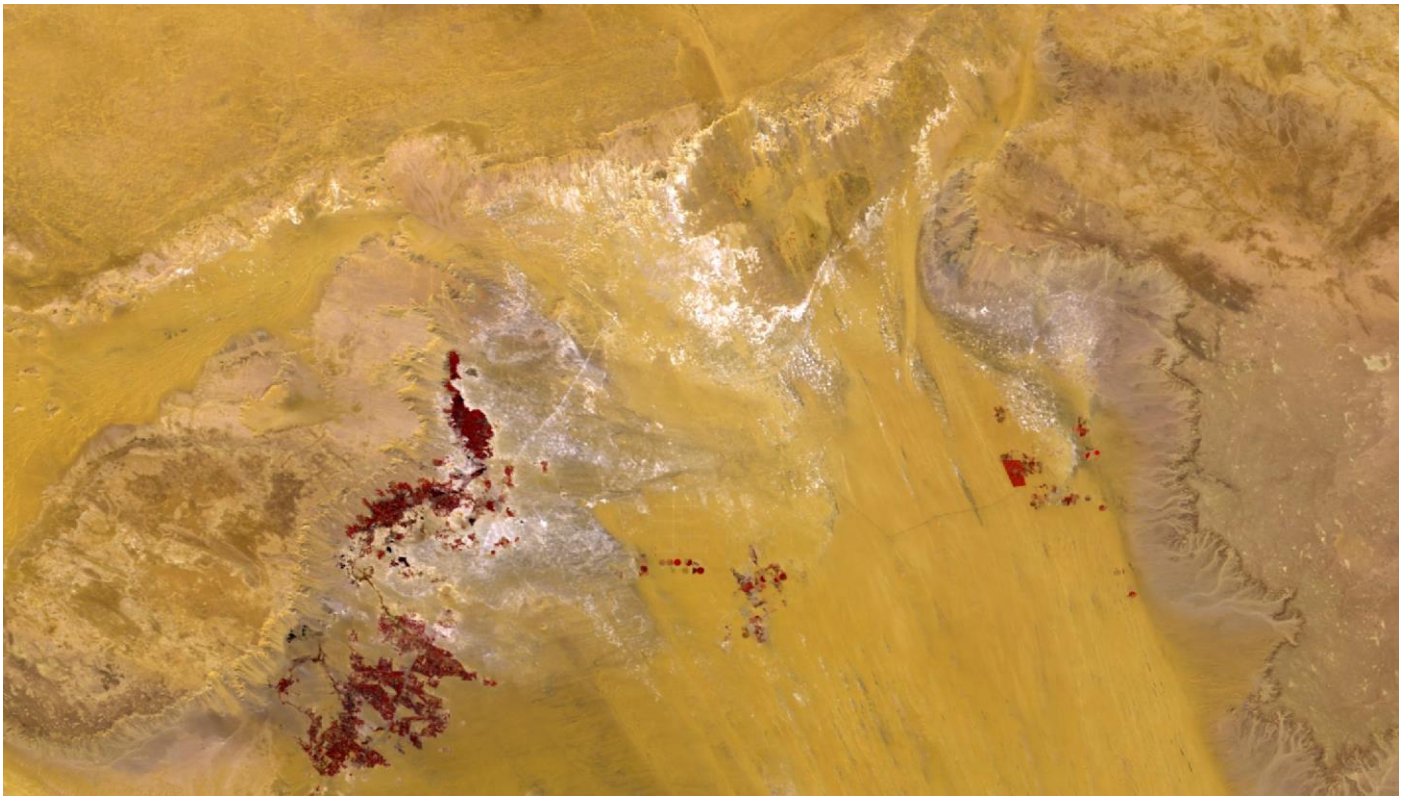
65. PROBAV_S1_TOA_X18Y05_20140921_100M_V101 (Sahara, Mali)

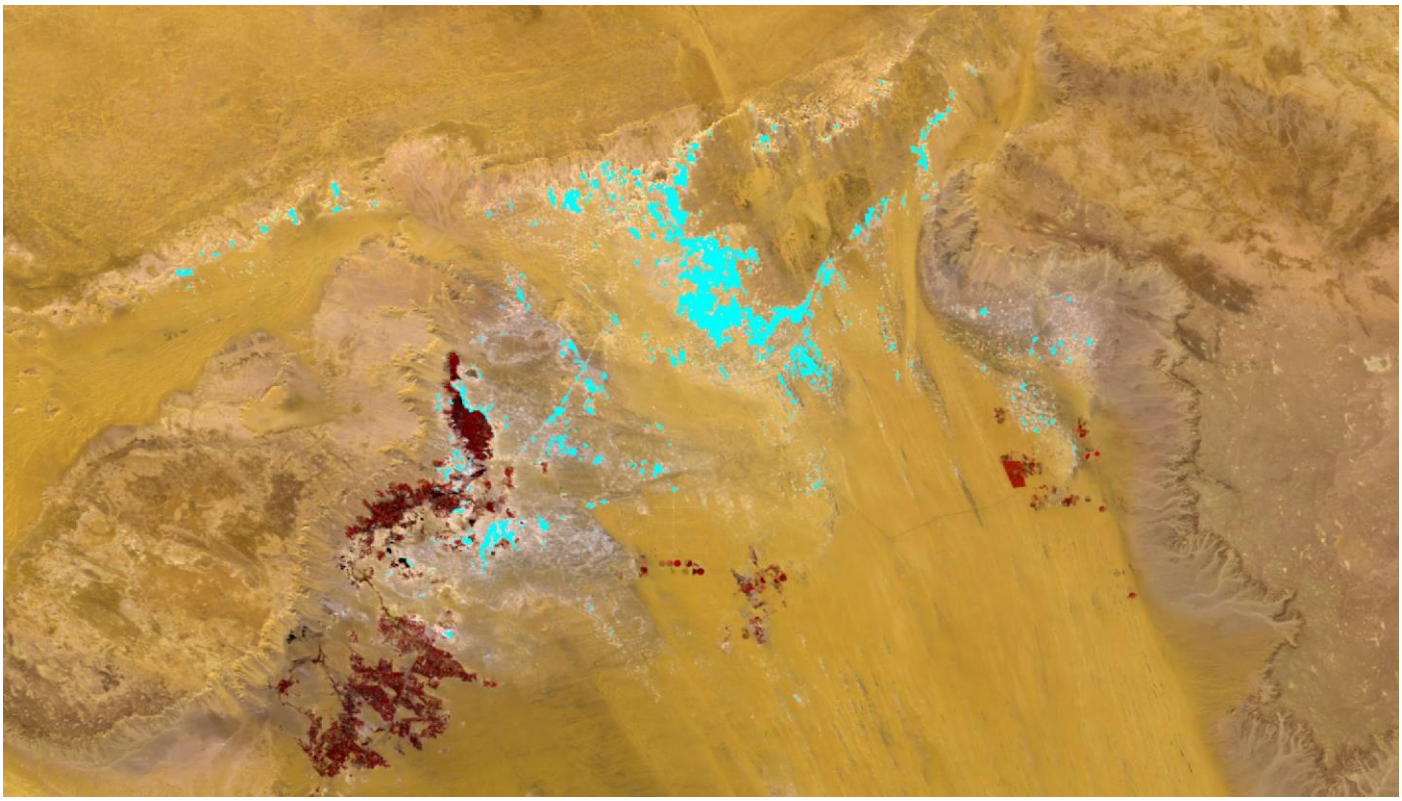




In the picture a huge field of very light translucent Cumulus clouds can be seen. They cover a bright large region of sandy desert. Without special contrasting approach and a trained eye, they are difficult to see. The computer-automated method couldn't make it.

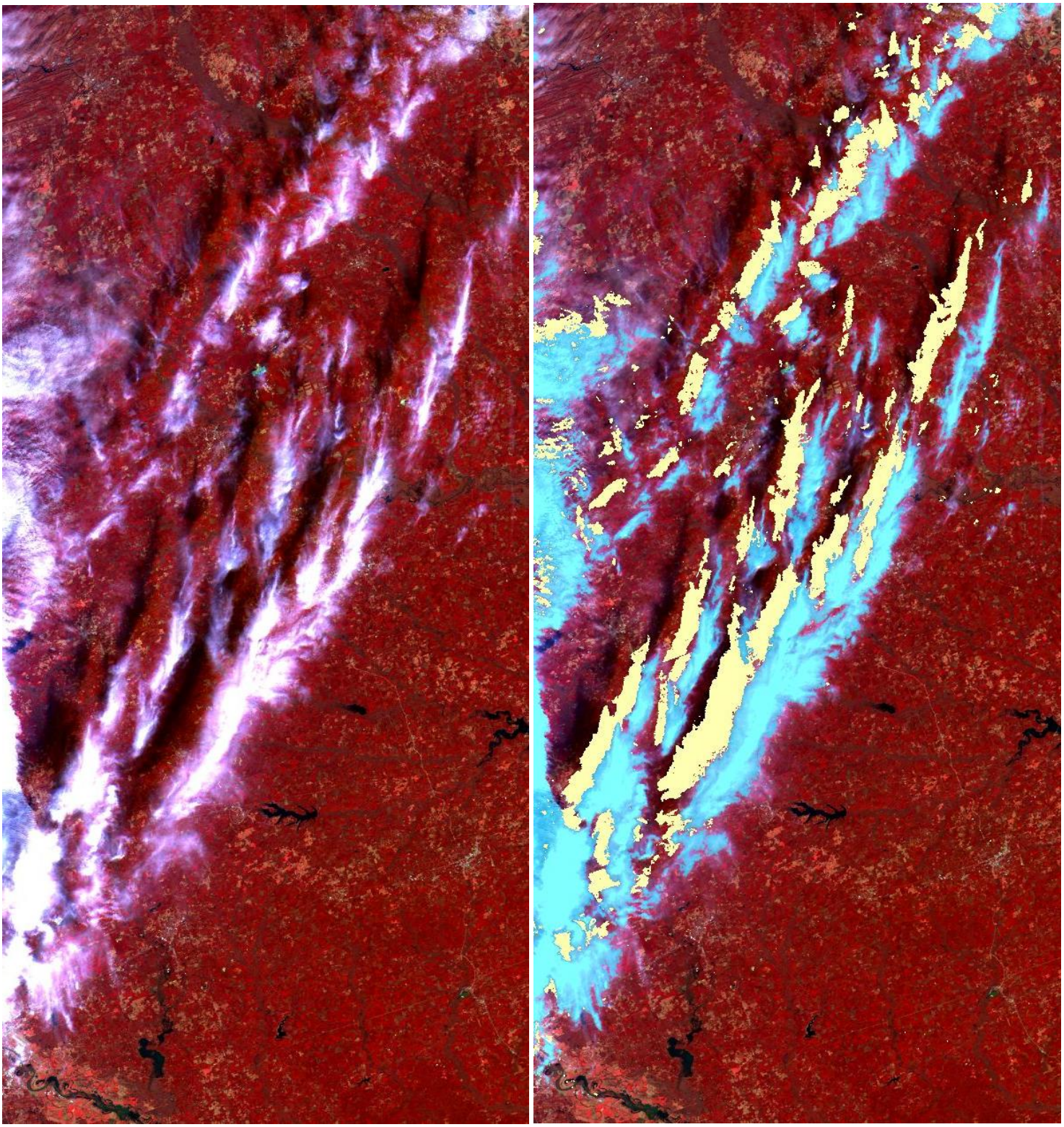
66. PROBAV_S1_TOA_X20Y04_20140921_100M_V101 (Egypt)





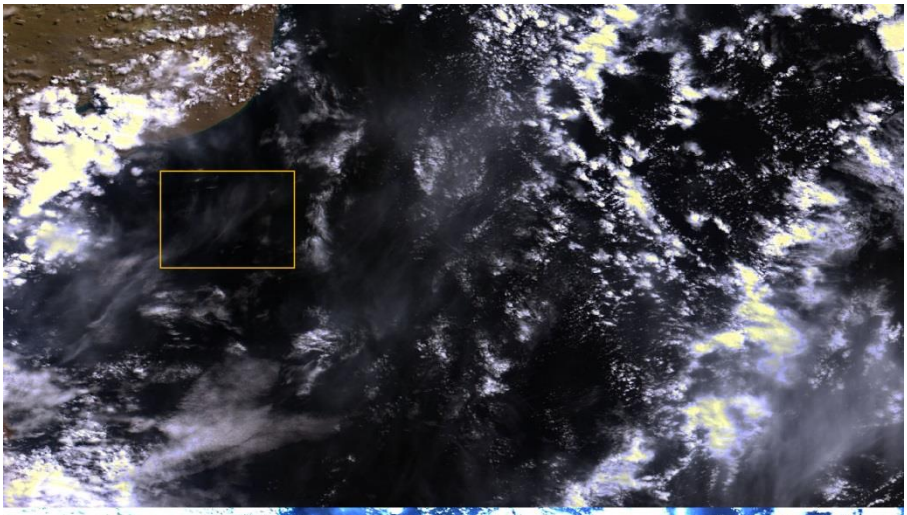
Some dry lake pixels (probably salt lake) were incorrectly determined to be cloudy.

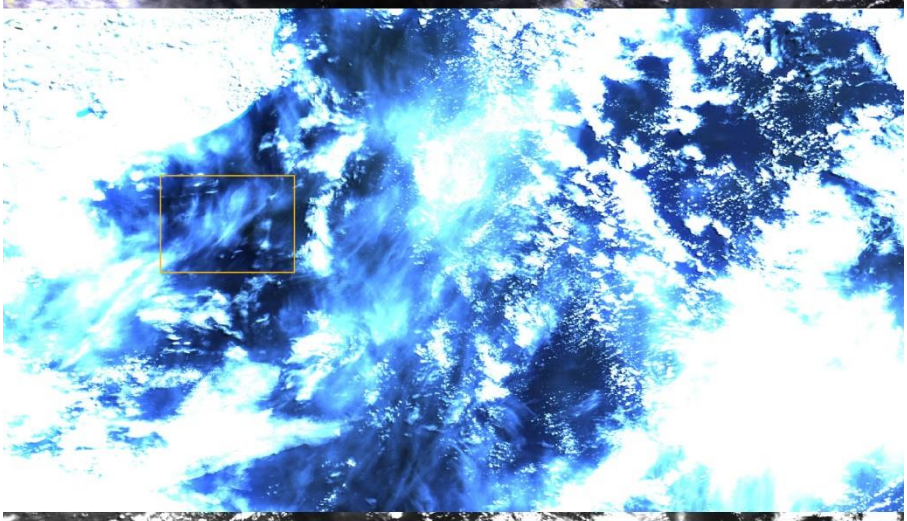
67. PROBAV_S1_TOA_X08Y04_20141221_100M_V101 (Texas)

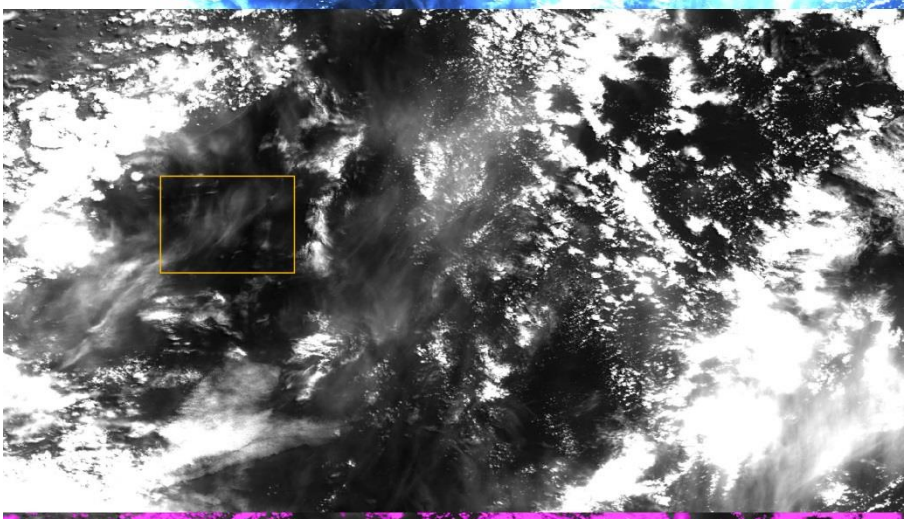


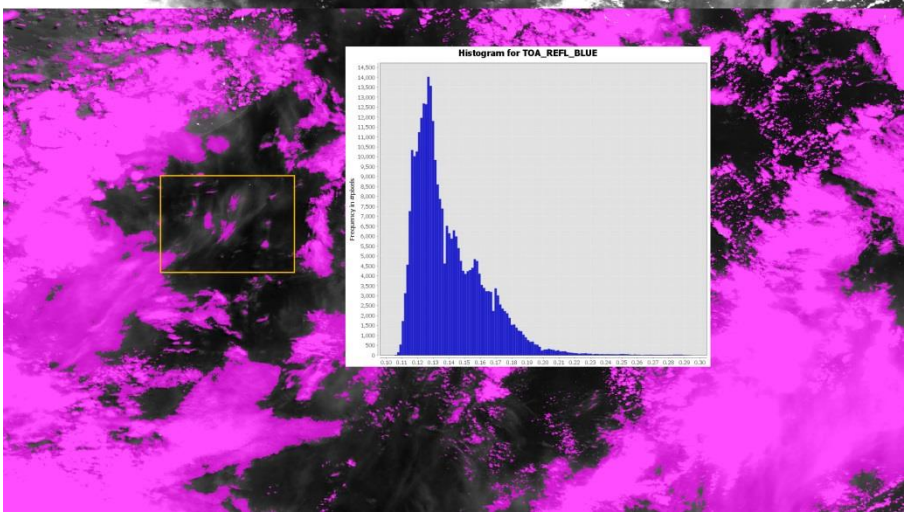
Incorrect determined of shadows location.

68. PROBAV_S1_TOA_X11Y12_20141221_100M_V101 (South Atlantic in the East of Patagonia)









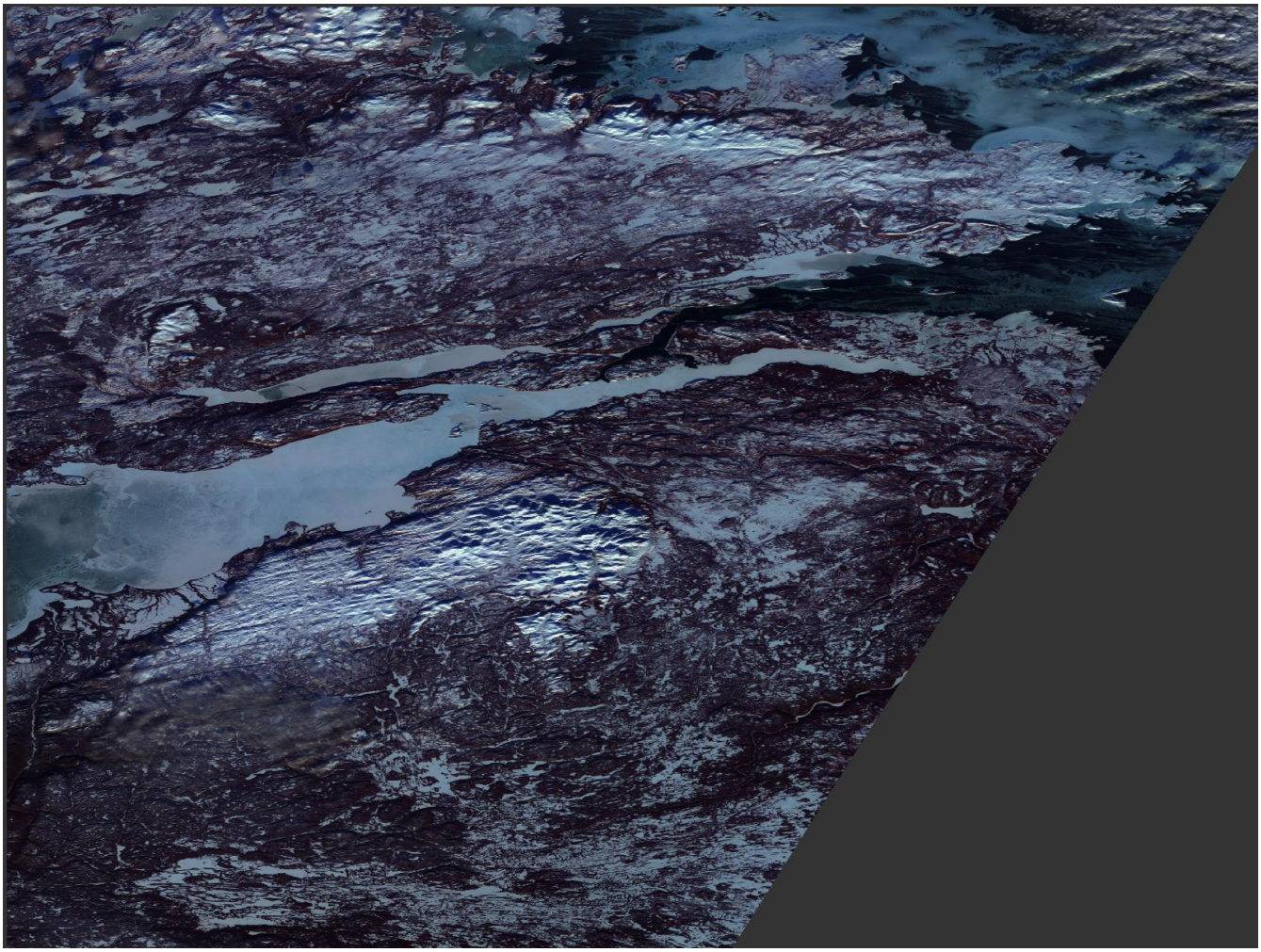
This is another example that points to the advantage of using a two-dimensional cloud detection method additionally.

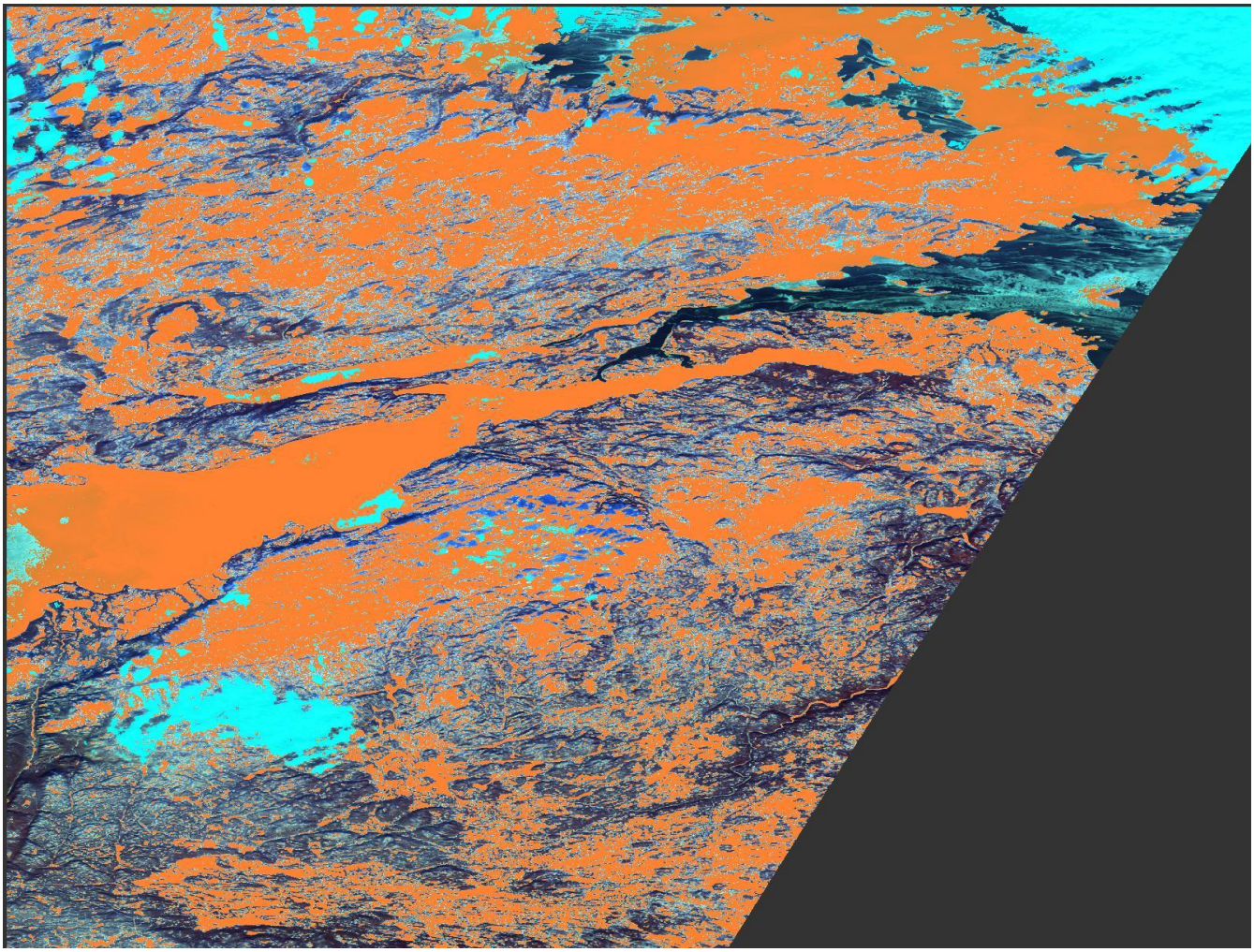
Large areas covered with translucent clouds can be seen in the top picture. A lot of these pixels were not identified as "cloudy".

Consider the rectangle marked with a yellow frame (on the left in the pictures). When contrasting (second picture above), it can be noticed that the rectangle is full of clouds.
If we calculate the histogram for this rectangle, for example, in the “BLUE” channel (third image from above), it will be seen that it is easy to choose a general criterion by which it is possible to compute a threshold for a most of the local areas and to recognize at least a significant part of unmasked clouds as such (last image).

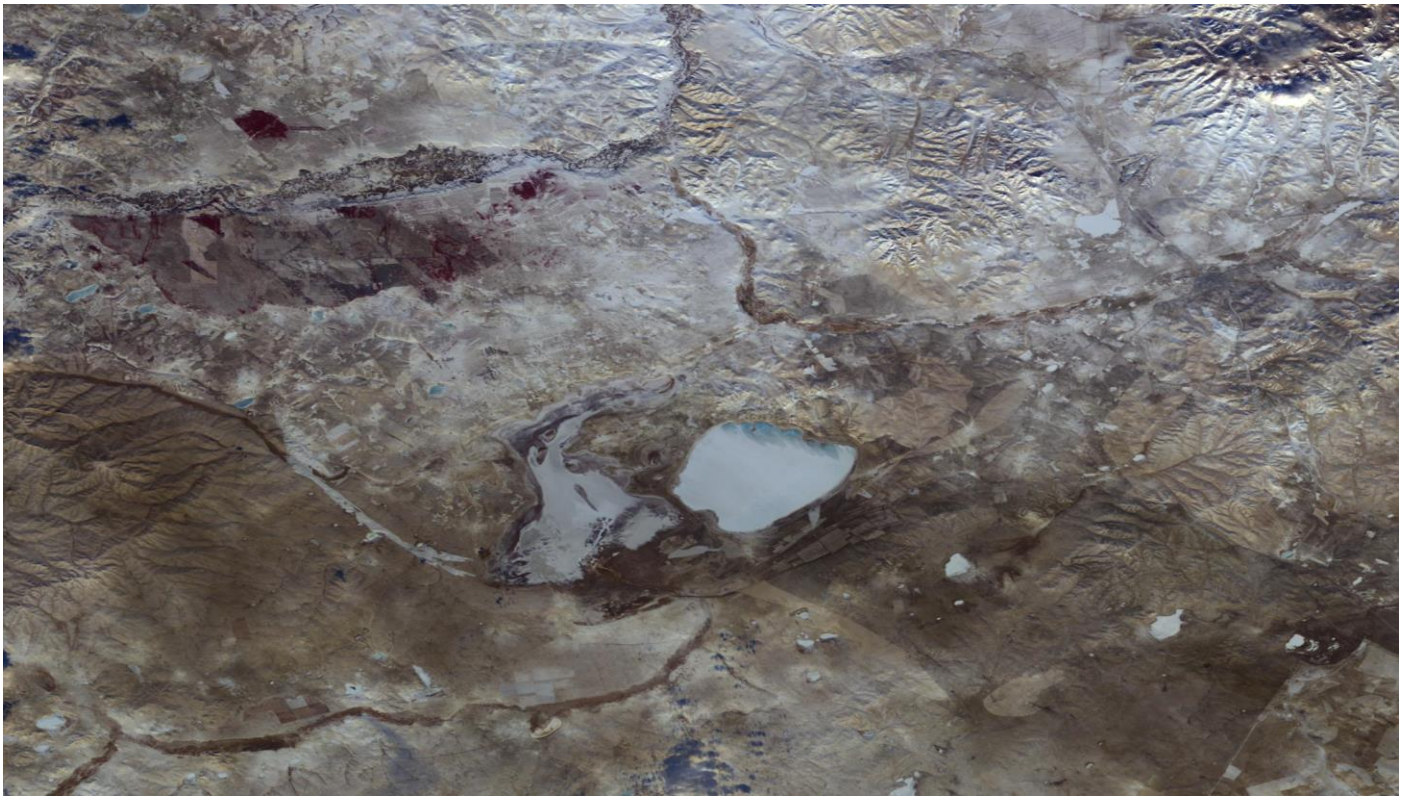
See also No. 9, No. 42.

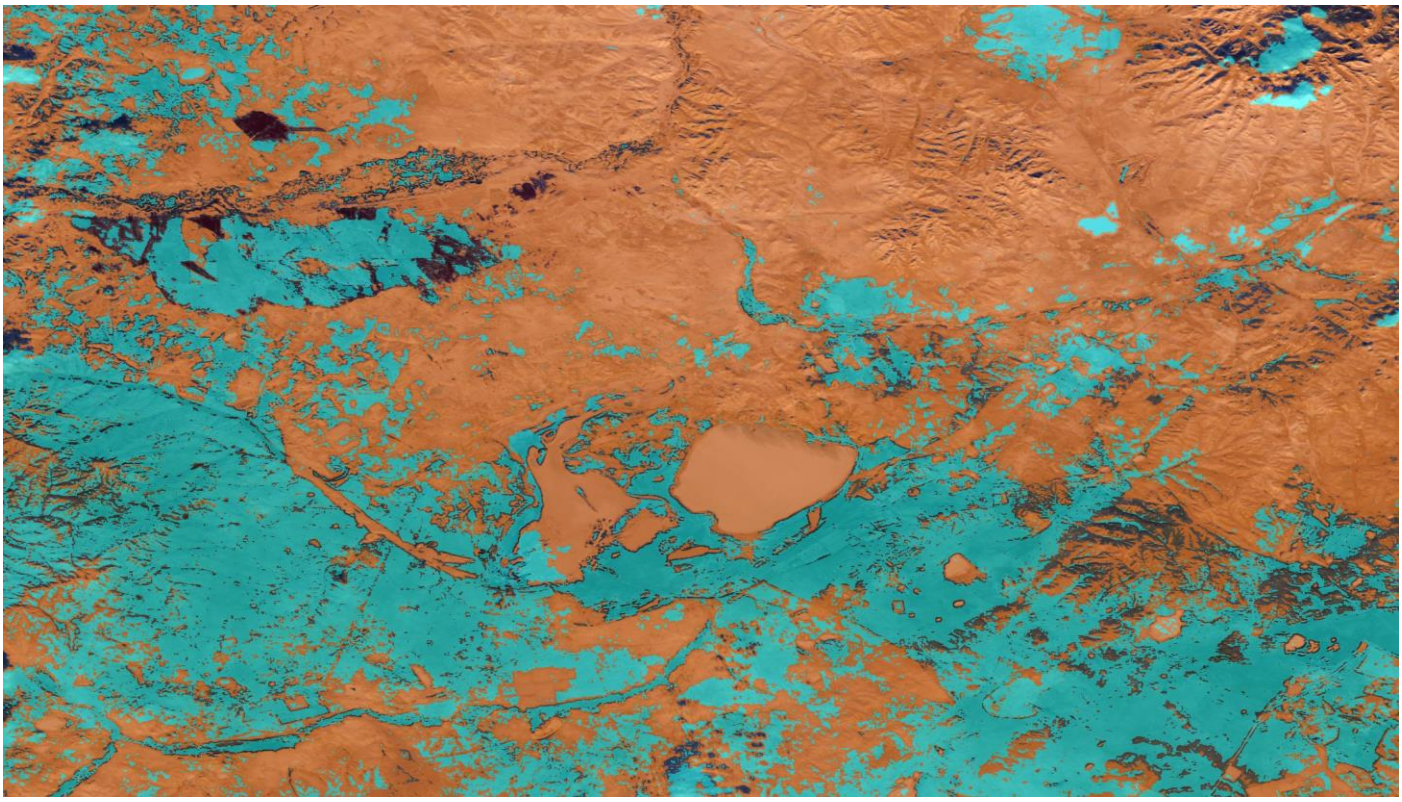
69. PROBAV_S1_TOA_X12Y02_20141221_100M_V101 (Newfoundland)





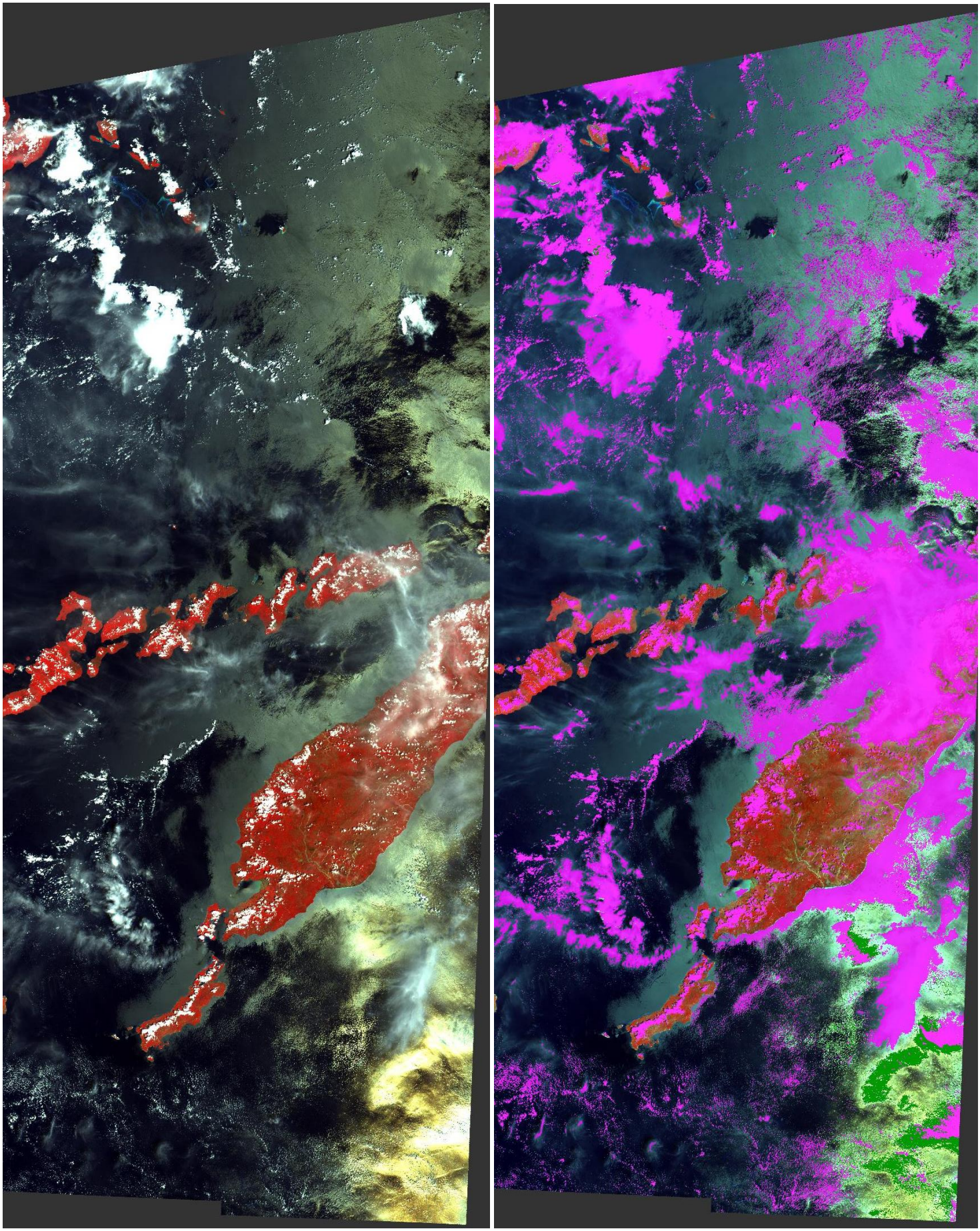
70. PROBAV_S1_TOA_X29Y02_20141221_100M_V101 (Lake Zun-Torey, Dahuria)





The data presented in the pictures № 69 and № 70 are very suitable for testing the cloud- and ice detection approach with regard to the differentiation of snow from clouds and detection only partially snow covered, or icy territories on land and water (№ 69). The same can be relevant also for the detection of snow-covered soil of the coniferous forests (№ 70) that I mark as "spatially-mixed land-snow/ice". Both pictures show that the mention method does not work reliably when it is applied.

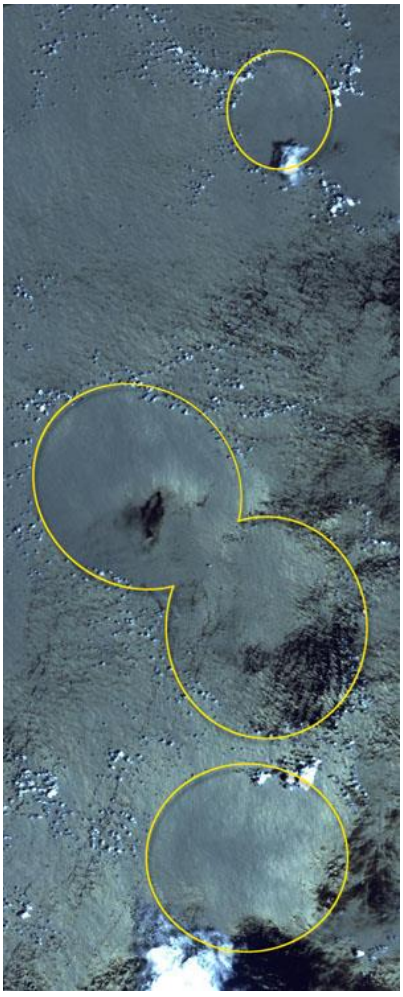
71. PROBAV_S1_TOA_X30Y08_20141221_100M_V101 (Sawu Sea, Banda Sea, Timor)



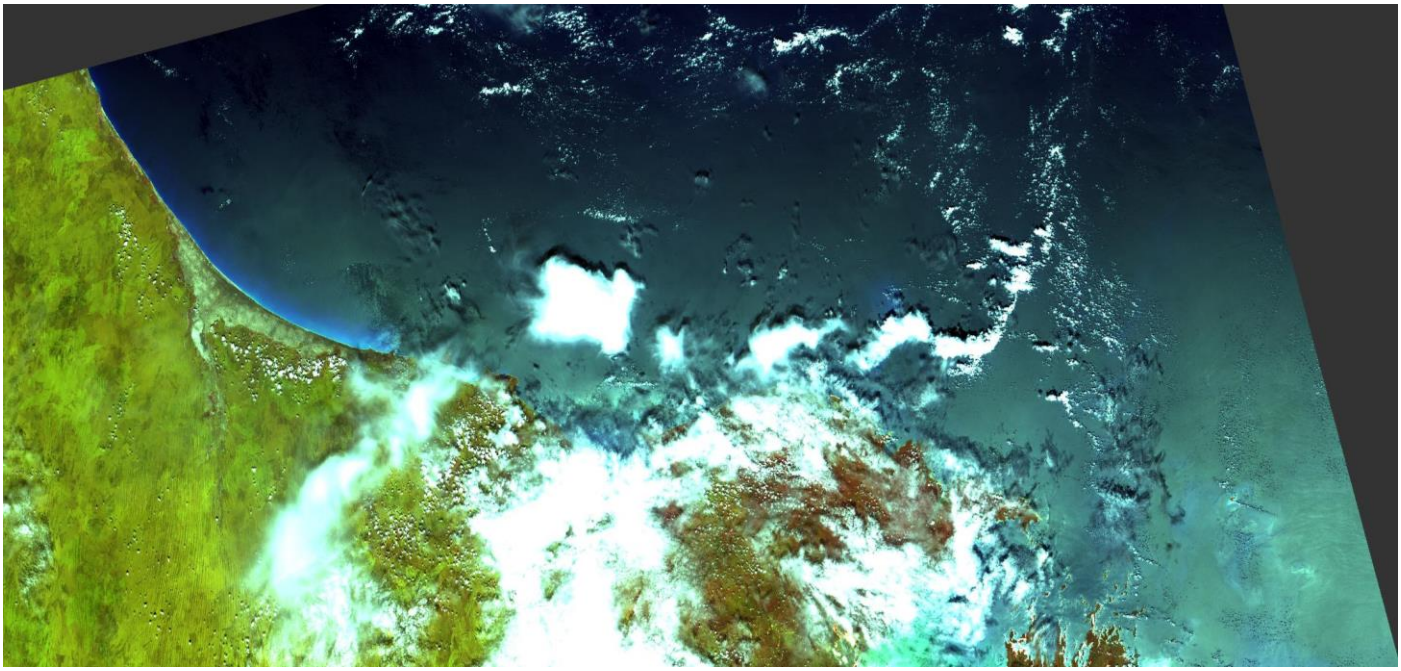
A lot of sun glint pixels were misidentified here: some as clouds (pink), others as ice (green).

This image (a fragment lies at the top right of the image № 71) has nothing to do with the research of C / I masks.

This is a nice picture, so to speak, which indicates "Cloud Arc" cloud structure. The structure is particularly noticeable on the bright sun glint water. It consists of a collection of small cumulus clouds, which are put together in a circle. In the middle a cloud-free surface can be seen, which indicates rising air.

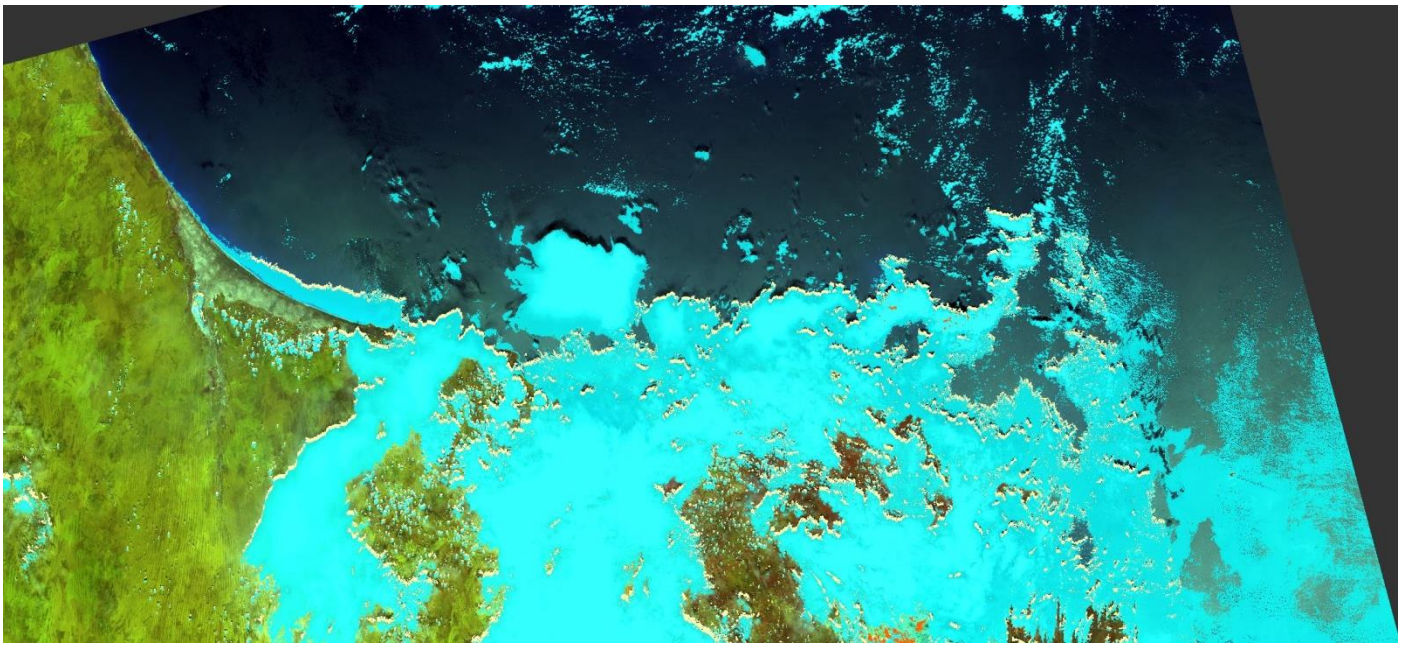


72. PROBAV_S1_TOA_X30Y09_20141221_100M_V101 (Eighty Mile Beach, Northwest Australia)

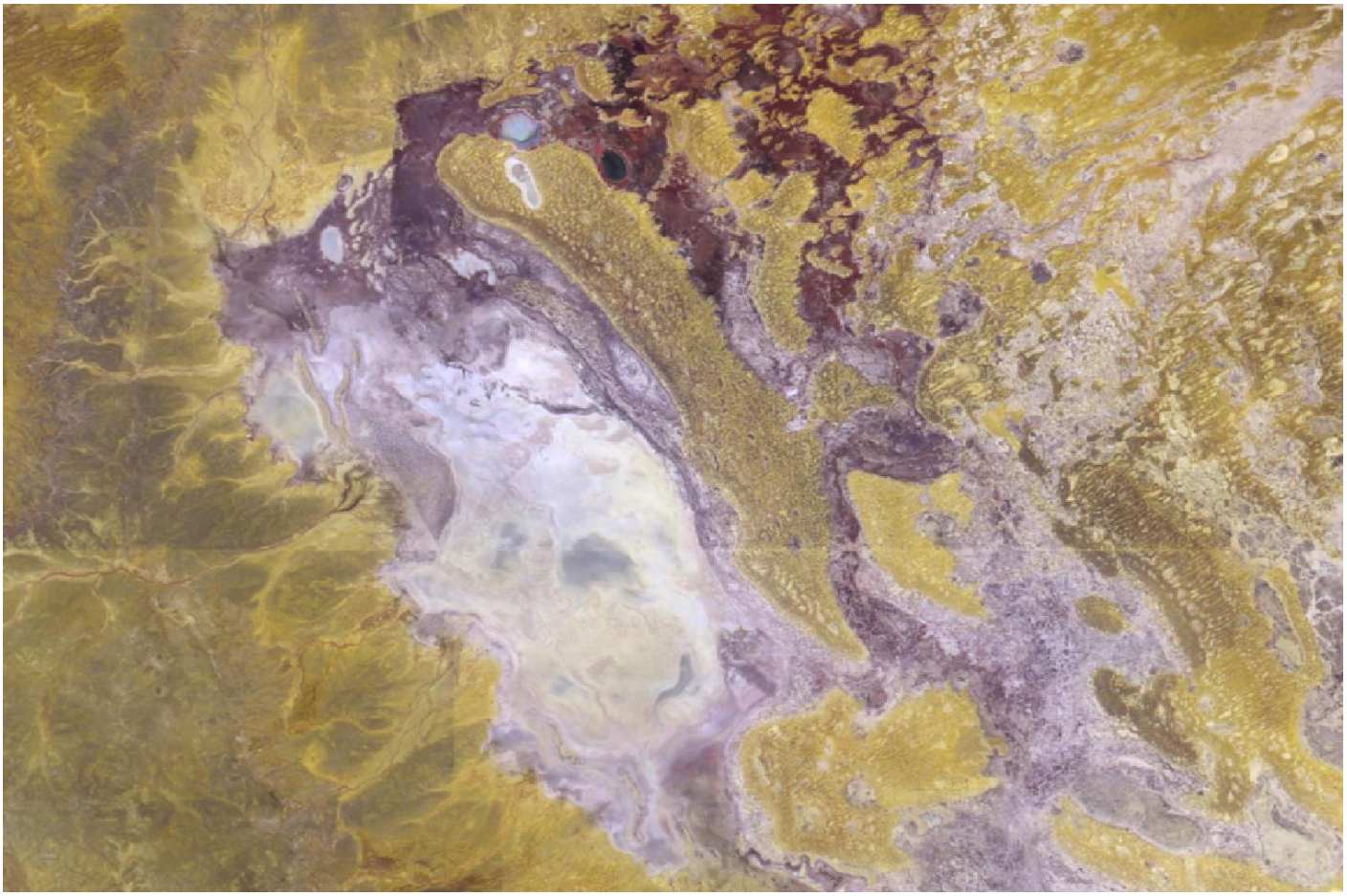


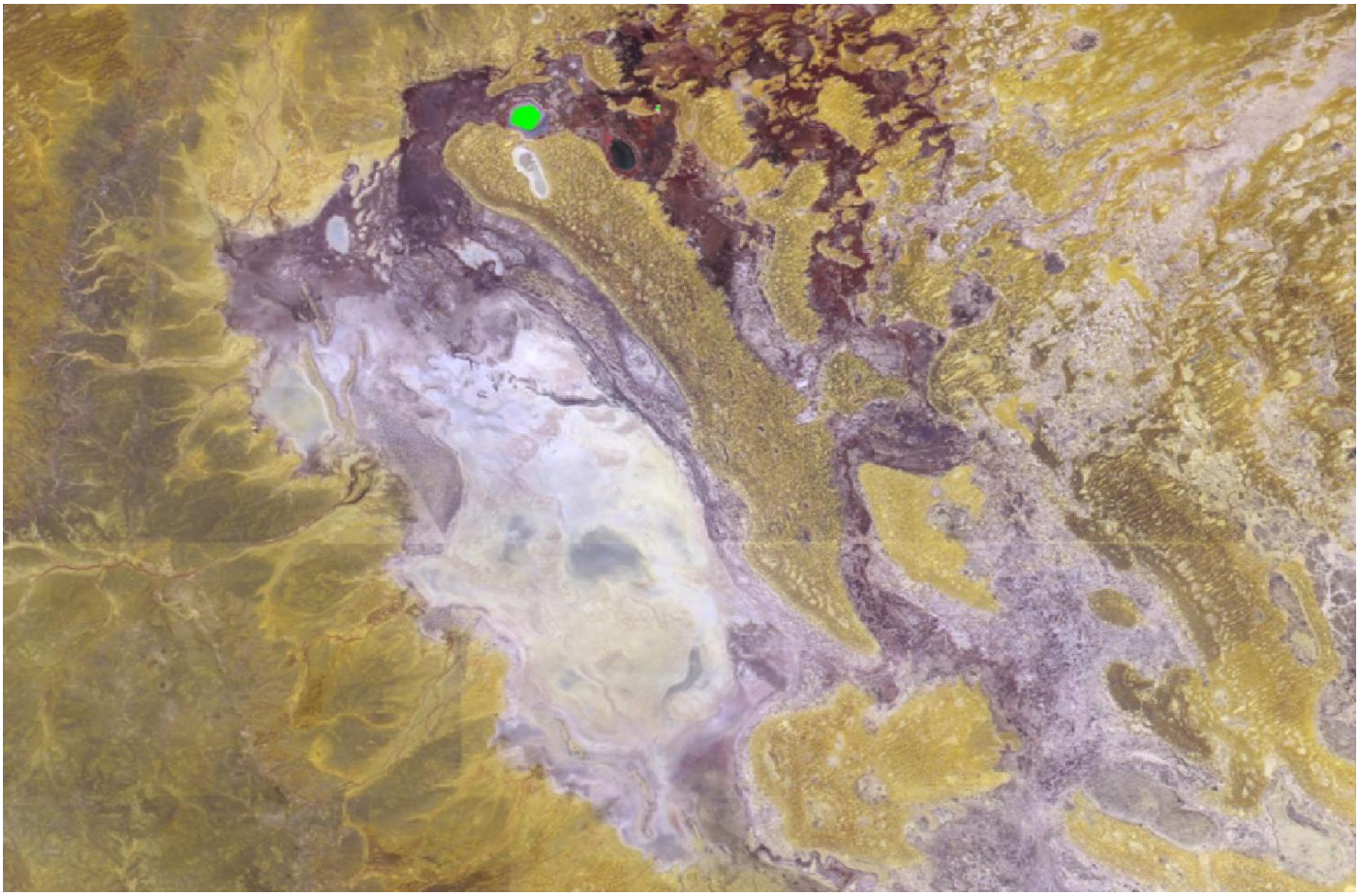
The wrong masking of sun glint pixel (in the right part of the picture) again.

← The middle picture shows an area of bright blue coastal waters. Maybe this is no longer a sun glint area, but everything is wrongly identified as "cloudy".



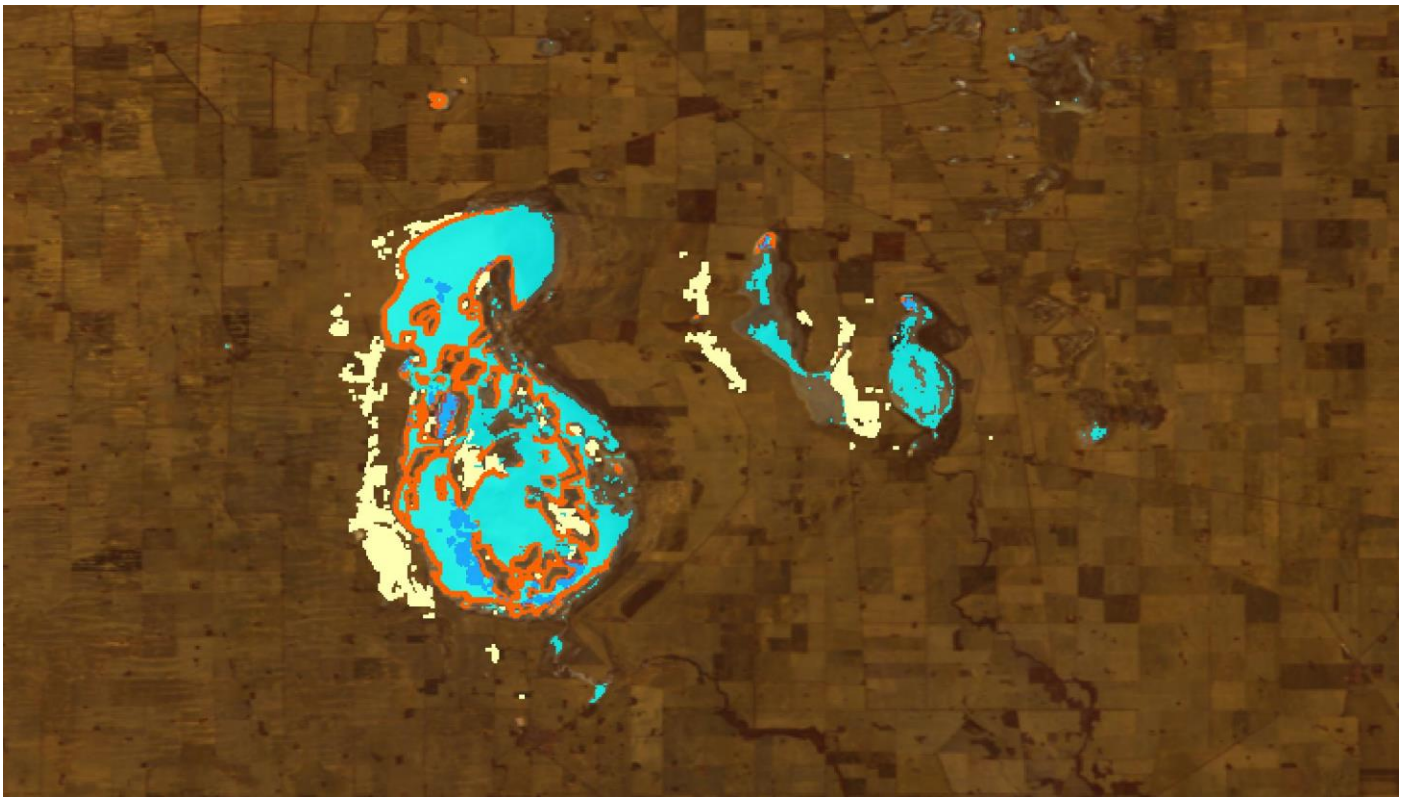
73. PROBAV_S1_TOA_X32Y10_20141221_100M_V101 (South Australia)





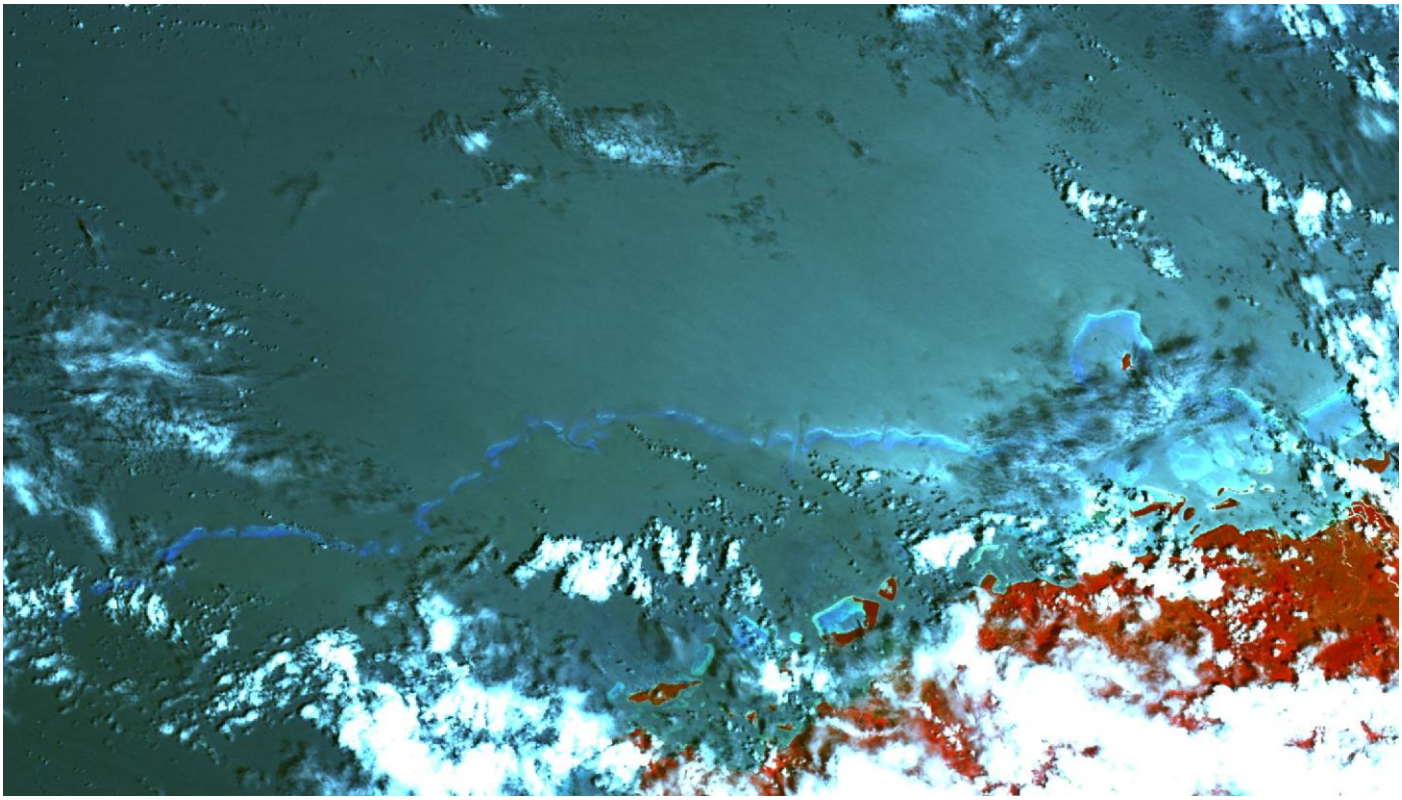
A dry (or salt) lake is incorrect masked as ice (green).

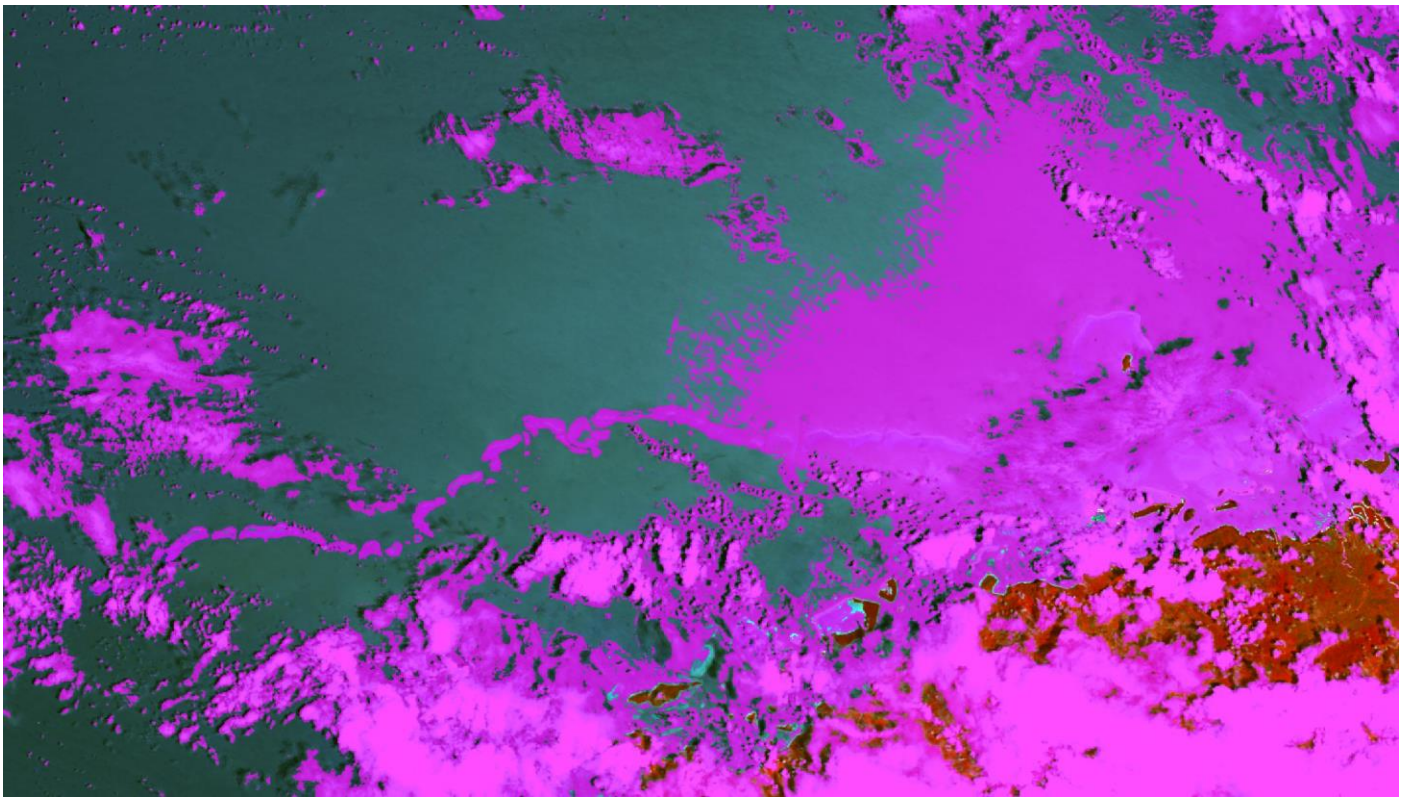
74. PROBAV_S1_TOA_X32Y11_20141221_100M_V101 (Lake Tyrrell, Australia)



The dry (salt?) clear sky lake is wrong masked as cloudy (blue)/icy (orange). Dark blue pixels are referred to “not good blue flag”, yellow - to cloud shadows that are not really exist.

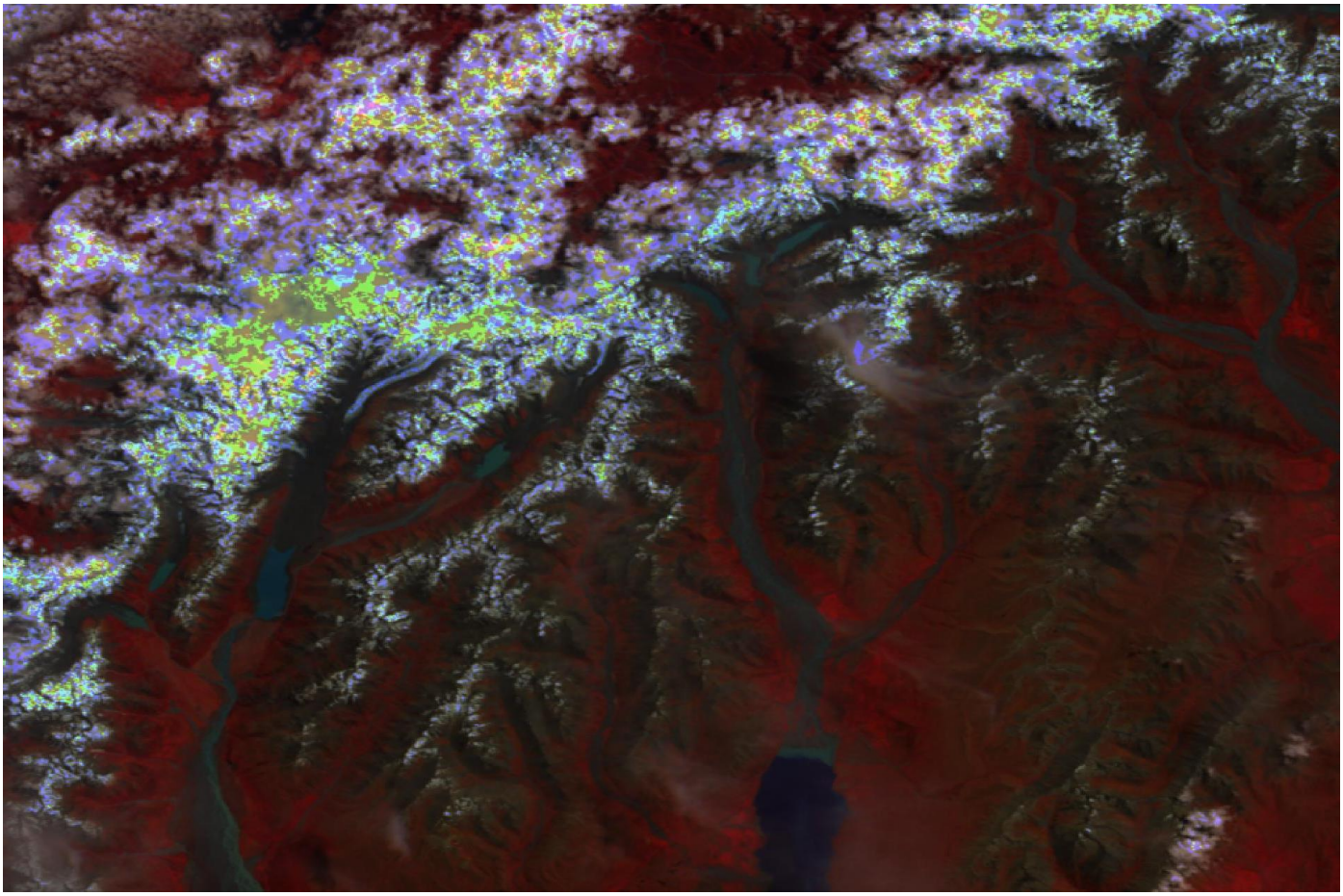
75. PROBAV_S1_TOA_X35Y09_20141221_100M_V101 (Great Sea Reef, Kia Island, Fiji)

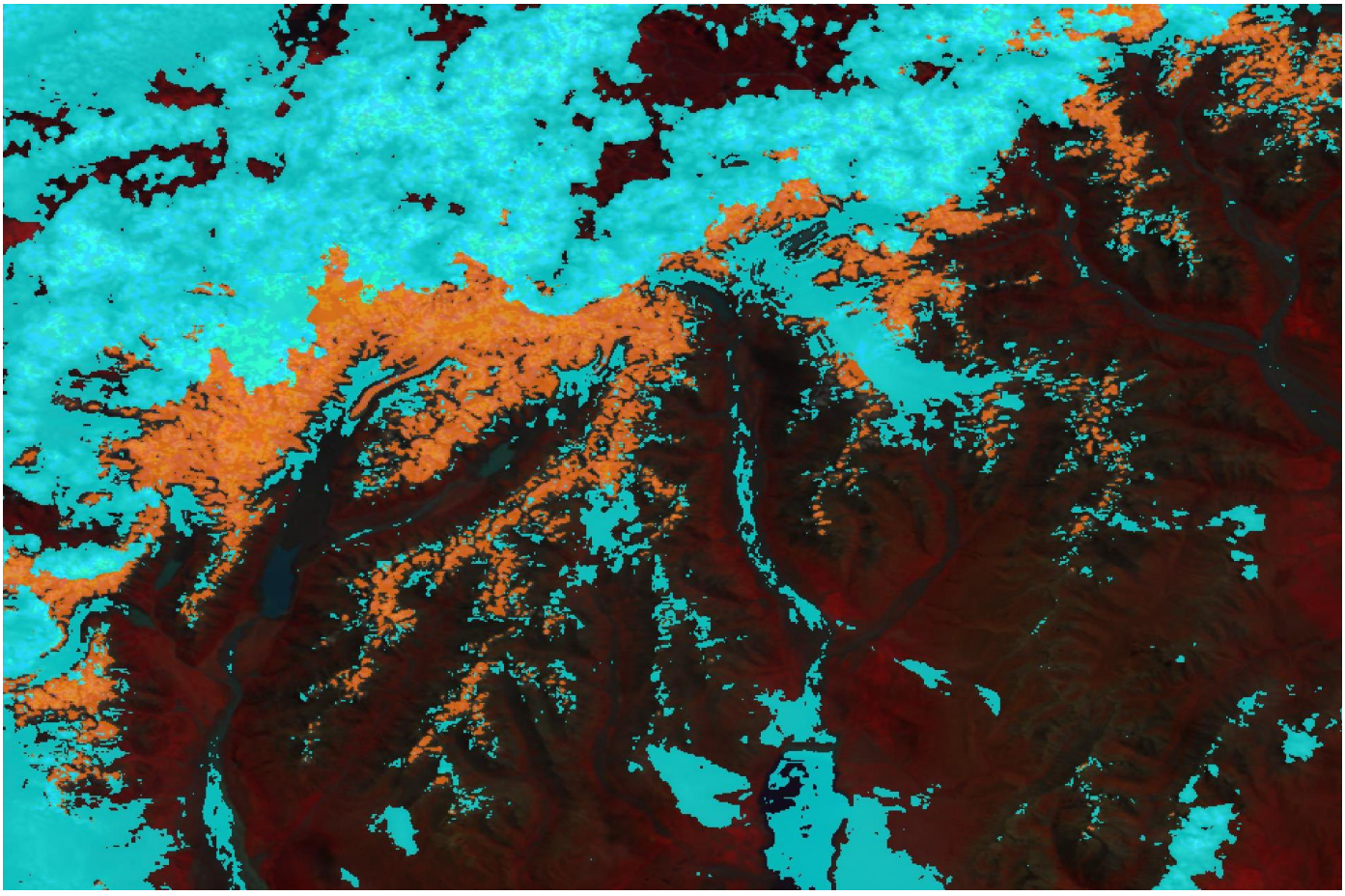




The chain of sand banks or coral islets covered with the bright water (as well as sun glint area on the right) is wrong recognized as cloudy (rose).

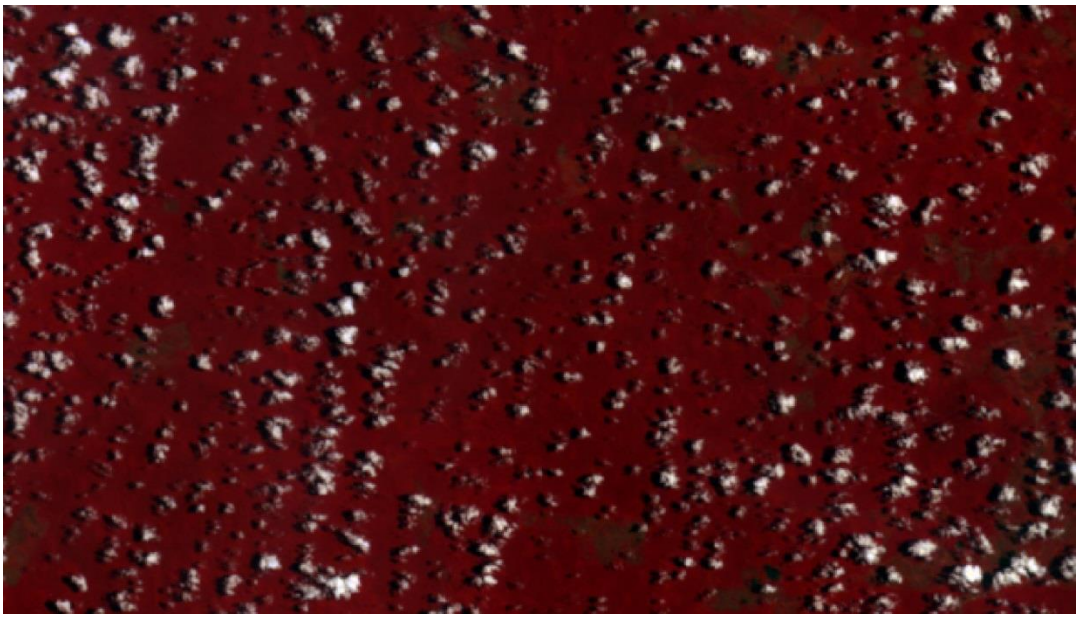
76. PROBAV_S1_TOA_X35Y11_20141221_100M_V101 (New Zealand Alps)



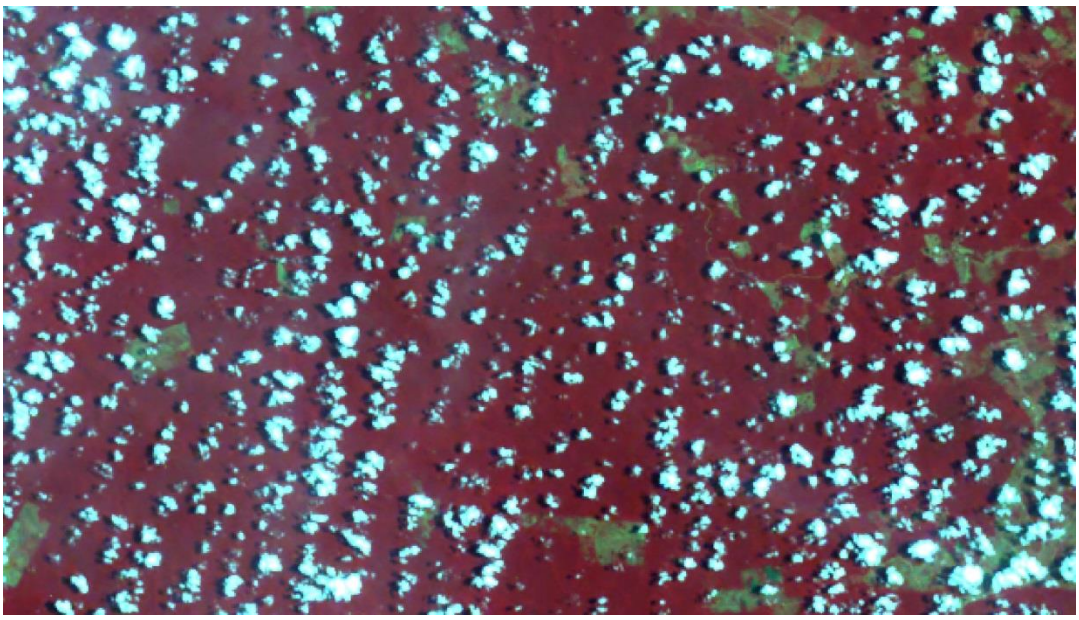


A lot of cloud pixels are preliminarily already marked (like on the№ 61). It confuses, it makes the visual recognition of cloudy and snow-covered pixels enormously difficult. In addition, many dark pixels of valleys and lakes seem to incorrectly indicate cloudy areas. Some areas that are only partially covered with snow are masked as “cloudy”.

77. PROBAV_S1_TOA_X12Y08_20140921_100M_V101 (Central Brazil)



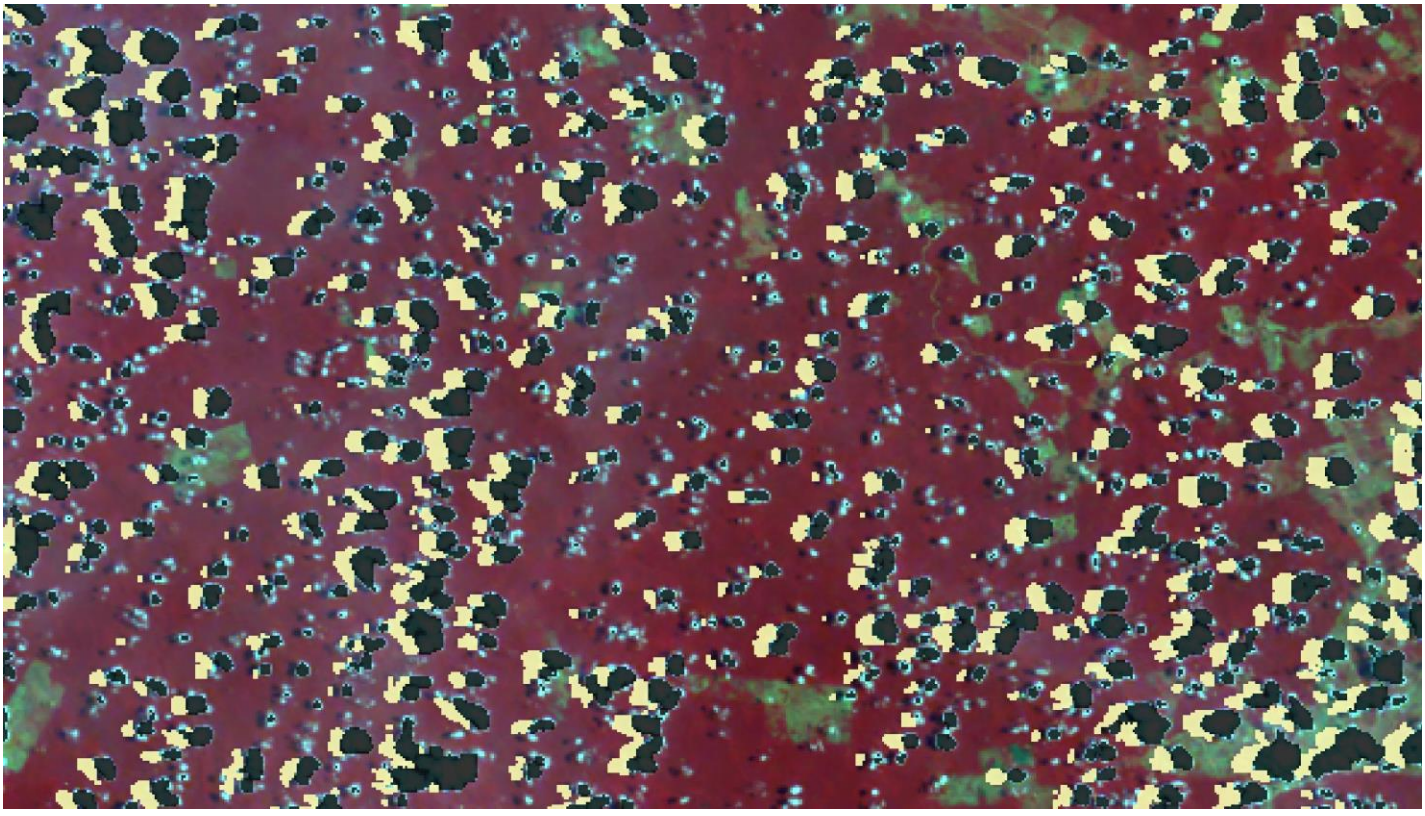
← Spatially mixed clouds



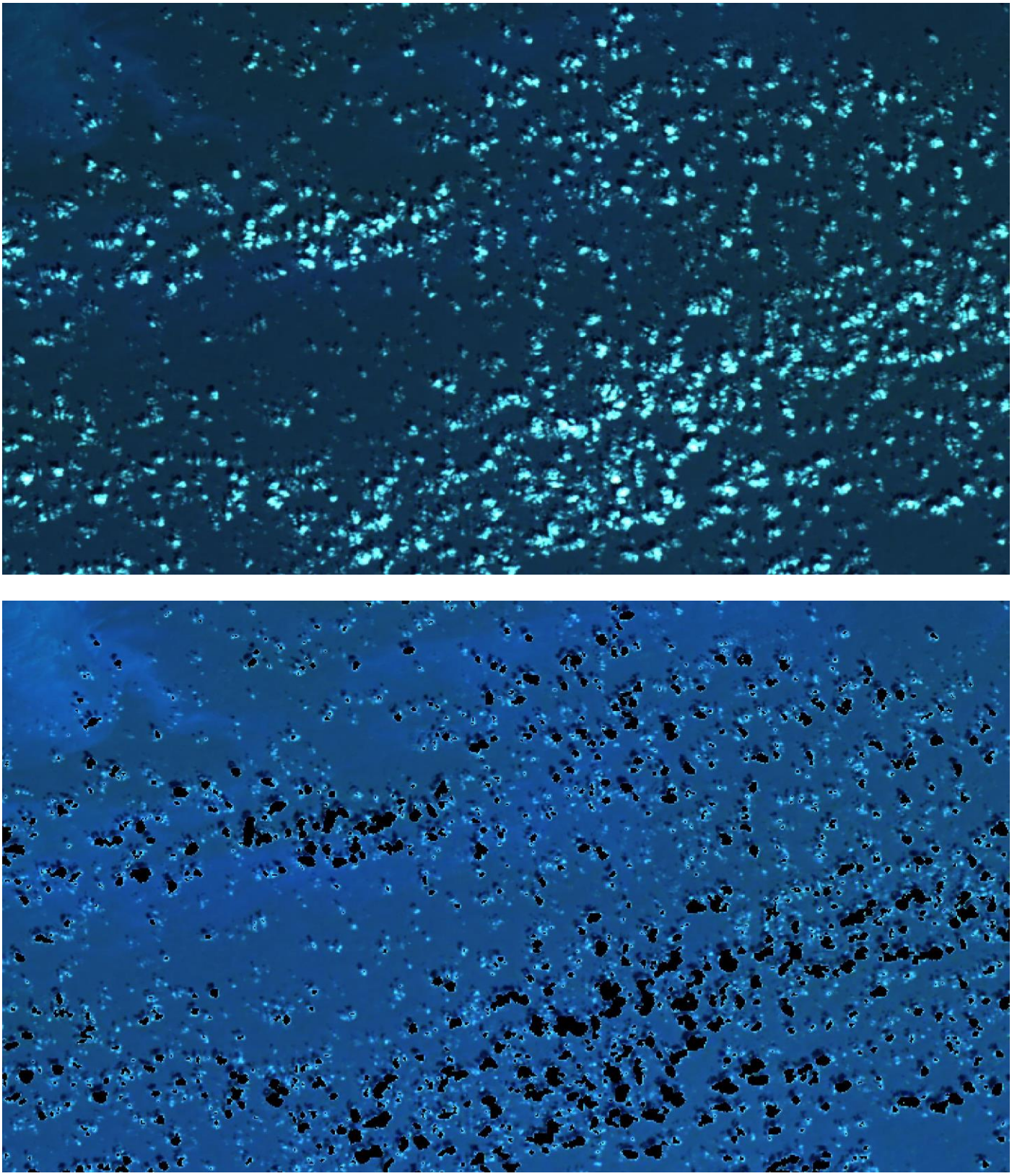
Spatially mixed cumulus clouds over the land are only partially recognized. The edges of small clouds are very transparent (because the size of the small cloud edge is much smaller than the pixel size), so for the most part they are not recognized (black cloud mask) as clouds.

← Spatially mixed clouds (contrasted)

↓ Cloud/Shadow mask



78. PROBAV_S1_TOA_X08Y04_20140921_100M_V101 (Gulf of Mexico)

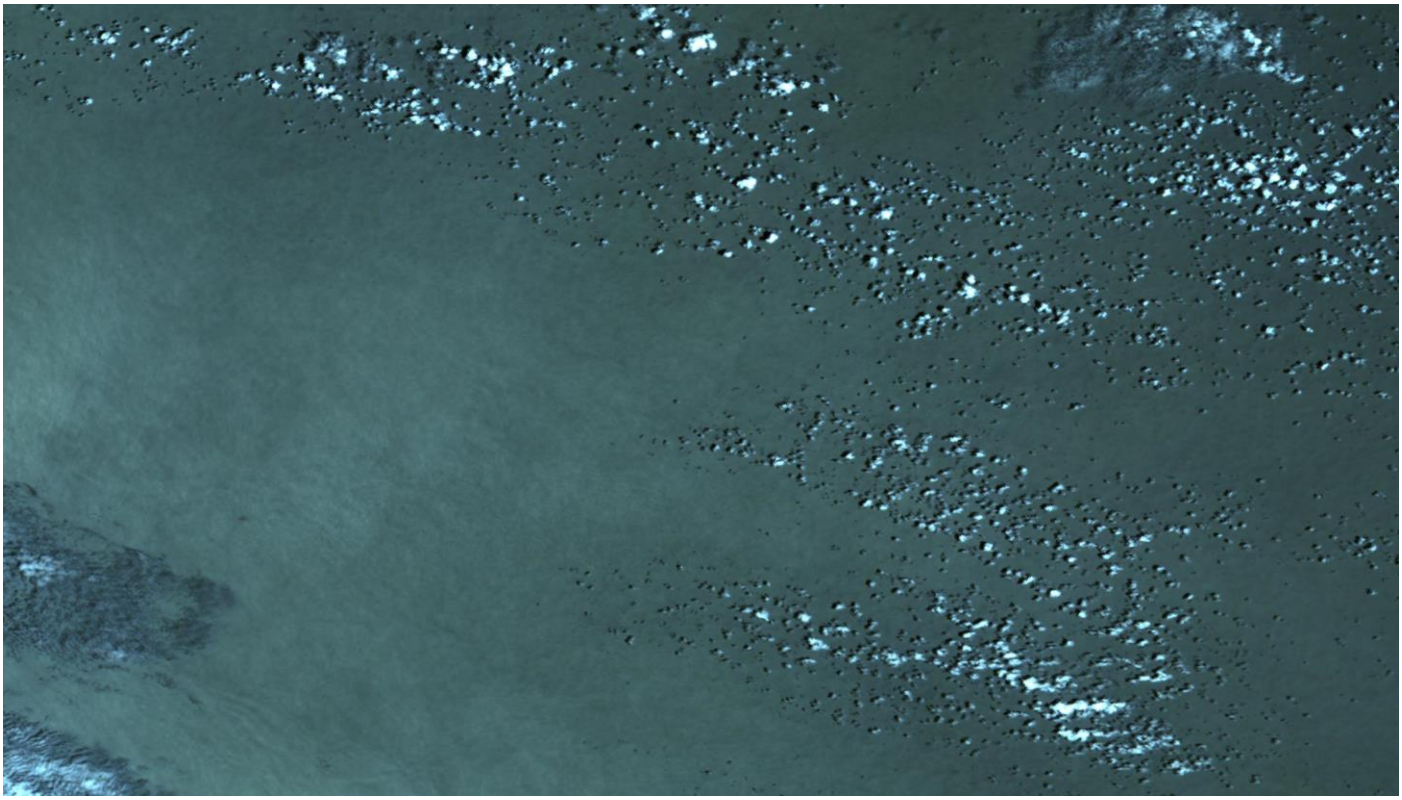


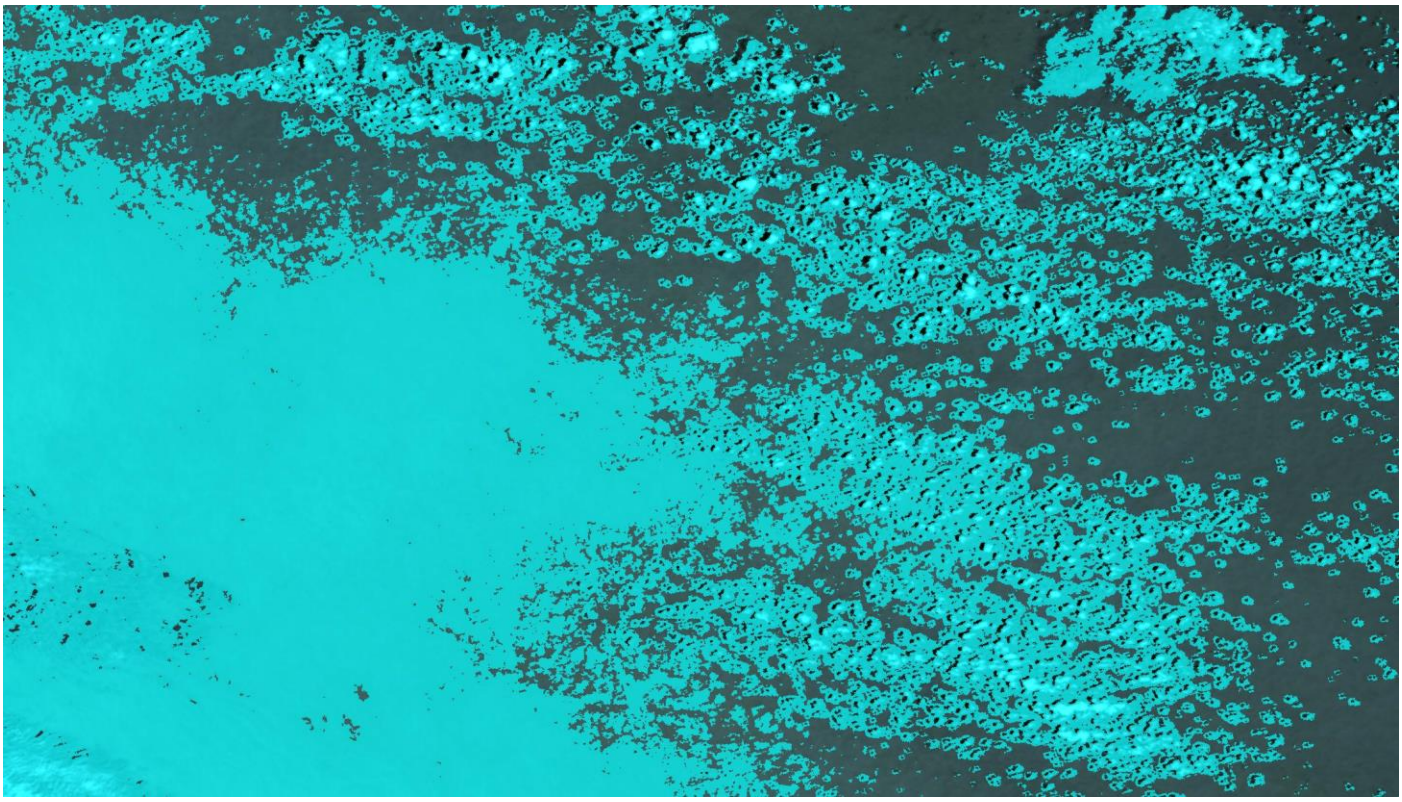
Spatially mixed cumulus clouds over the water are only partially recognized. The edges of small clouds are very transparent (because the size of the small cloud edge is much smaller than the pixel size), so for the most part they are not recognized (black cloud mask) as clouds.

79. PROBAV_S1_TOA_X19Y10_20140921_100M_V101 (South Atlantic in the southwest of Namib)

Short chains of small cumulus clouds (cloud streets) were mostly not recognized as clouds.

80. PROBAV_S1_TOA_X15Y03_20140621_100M_V101 (Atlantic Ocean in the East of Azores)





Sun glint effect interferes with cloud recognition fundamentally, because it itself is incorrectly identified as a cloud. This especially affects thin, light and semi-transparent clouds. In represented case, with small Cumulus, almost all of these clouds are recognized as such, but it is not clear whether they were recognized because of the clouds or because of the sun glint. The shadows cast are relatively dark. Therefore, they are not recognized as clouds. And it is correct.