Proba-V Cloud Detection Round Robin (PV-CDRR): Validation Results and Recommendations

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PV-CDRR Design

Deliverables:

- Validation Dataset Description ATBD– Algorithm providers
- Validation Report
- Final Workshop (1 March 2017)
- Conference proceeding/peer-reviewed paper (Multitemp 2017)

Round Robin Protocols

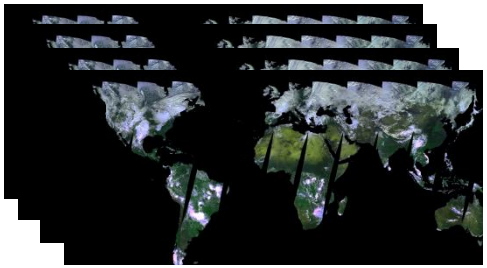
Input data in cloud toolbox

Algorithm Providers

- Algorithm 1
- Algorithm 2
- ...
- Algorithm n

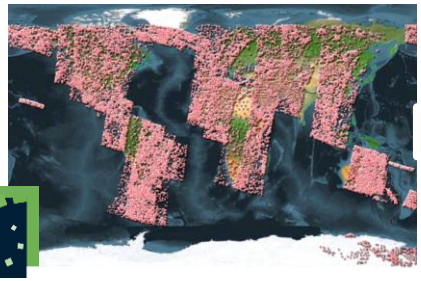
Cloud Masks

Input data (L2a, 333m)



Test Data

Validation data



Validation Data

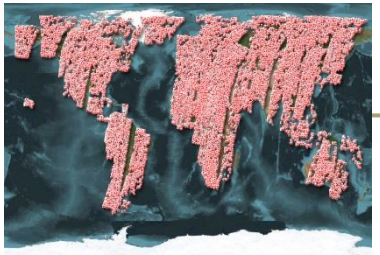
Quality Assessment

Confusion Matrices

Actual Class \ Predicted Class	Yes	No
Yes	TP	FN
No	FP	TN

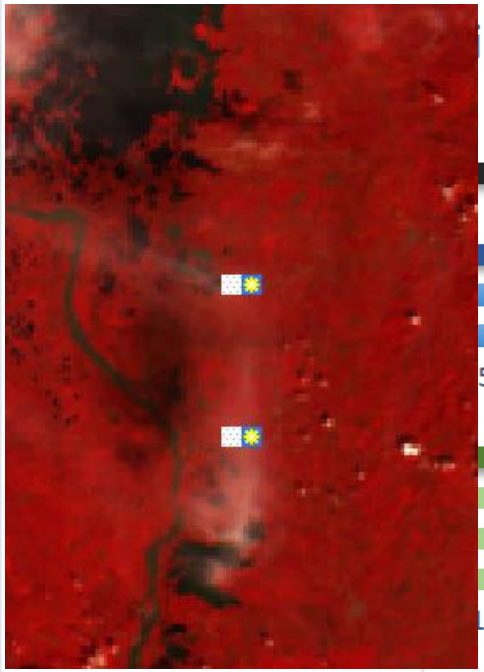
Visual inspection

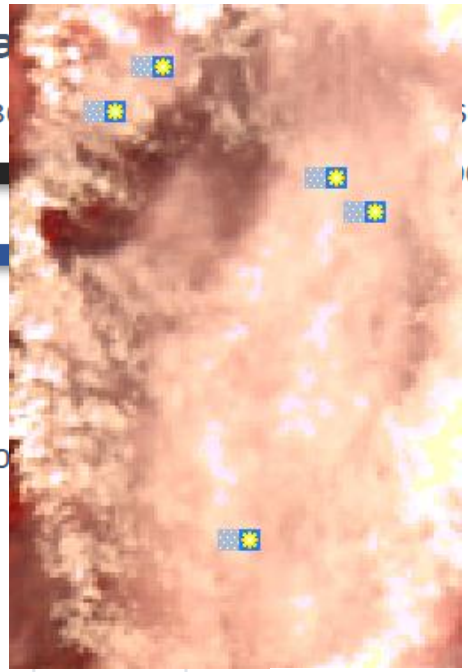
Validation Dataset – Pixel Collection



Include a range of environmental conditions and a range of surface types

- 70% land
- 15% snow/ice
- 15% water





Other	4987
Floating ice	2751
Glint	1265
Cloud shadow	971

- Thick semi-transparent cloud
- Average density semi-transparent cloud
- Thin semi-transparent cloud
- Day

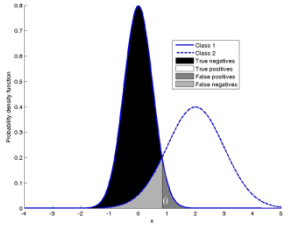
Algorithms Methods

Algorithms

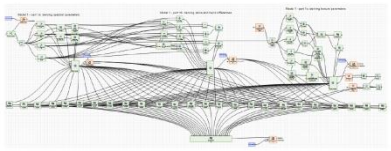
Algo1.Seviri and Modis cloud mask; Globcover mask

Algo2.Seviri cloud mask; Globcover mask

Algo3.Modis cloud mask; Globcover mask



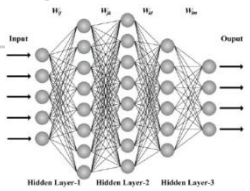
Algo1-3. Cumulative Discriminant Analysis



Algo4. Multi-spectral and multi-textural thresholding

Land Cover data of the ESA CCI

Algo5.Multilayer Perceptron (MLP) Neural Network

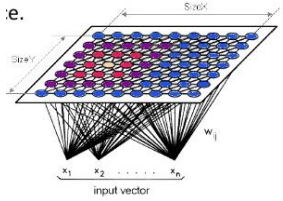


ERA-interim; DEM (GTOPO 30); GlobAlbedo surface reflectance

Algo8.Classification based on Cloud Optical Thickness

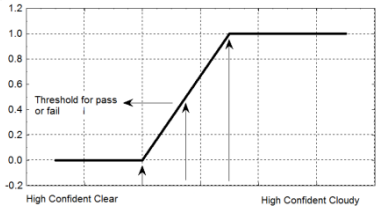
Algo6.Kohonen Self-Organizing Maps

Modis cloud mask

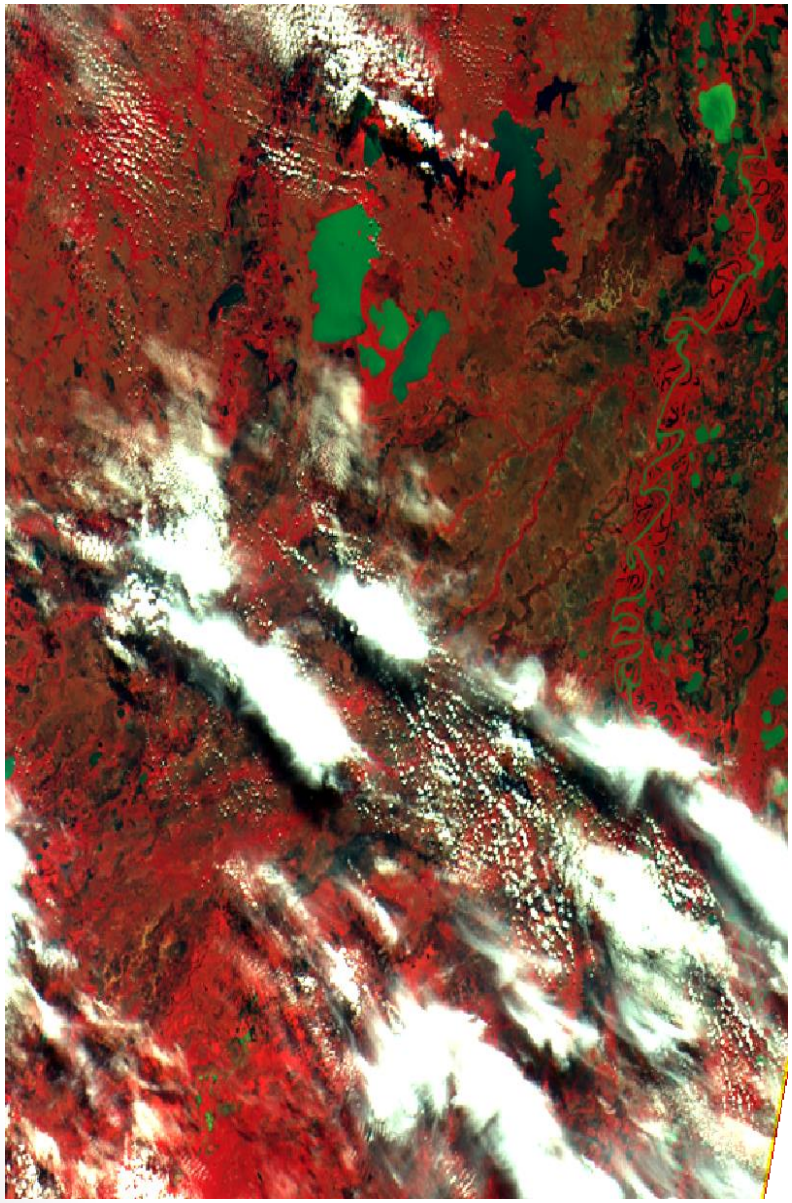


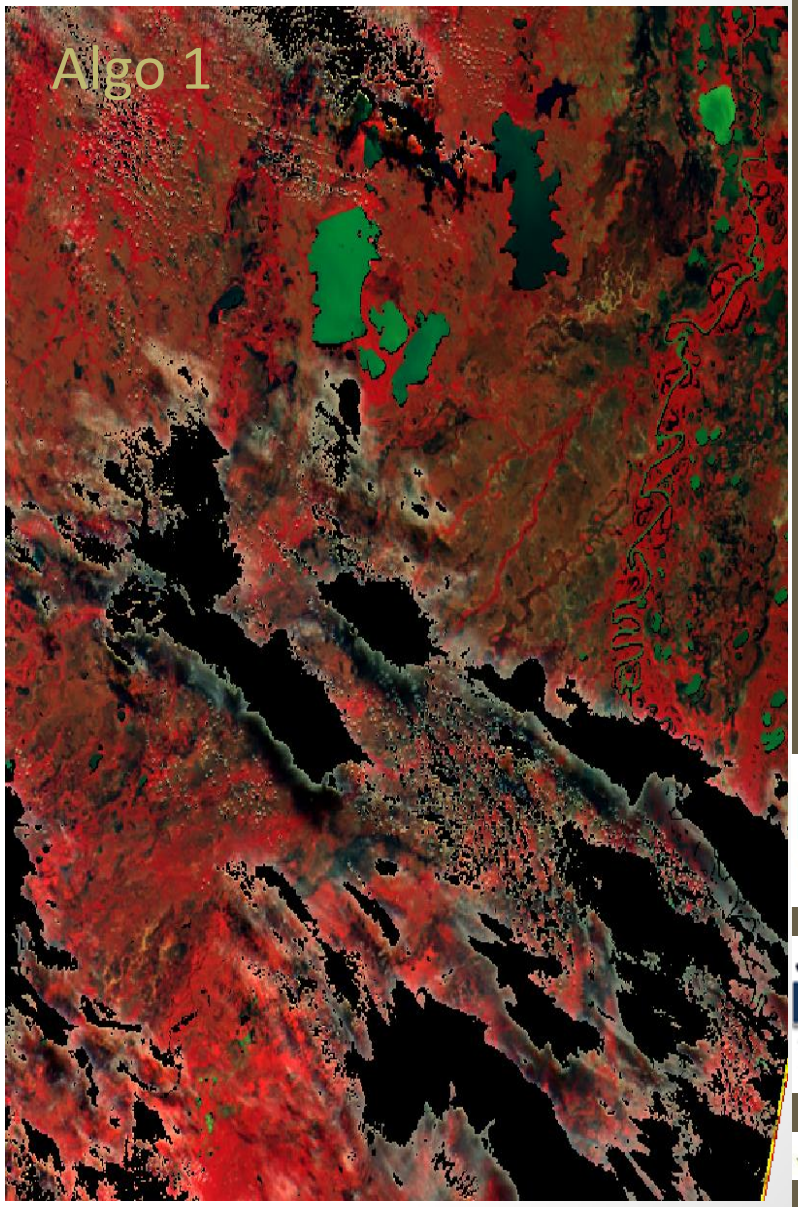
Land Cover data of the ESA CCI; GlobAlbedo surface reflectance

Algo7.Dynamic Thresholding



Assessment – Thick and semi-transparent clouds over land and behaviour over inland waters





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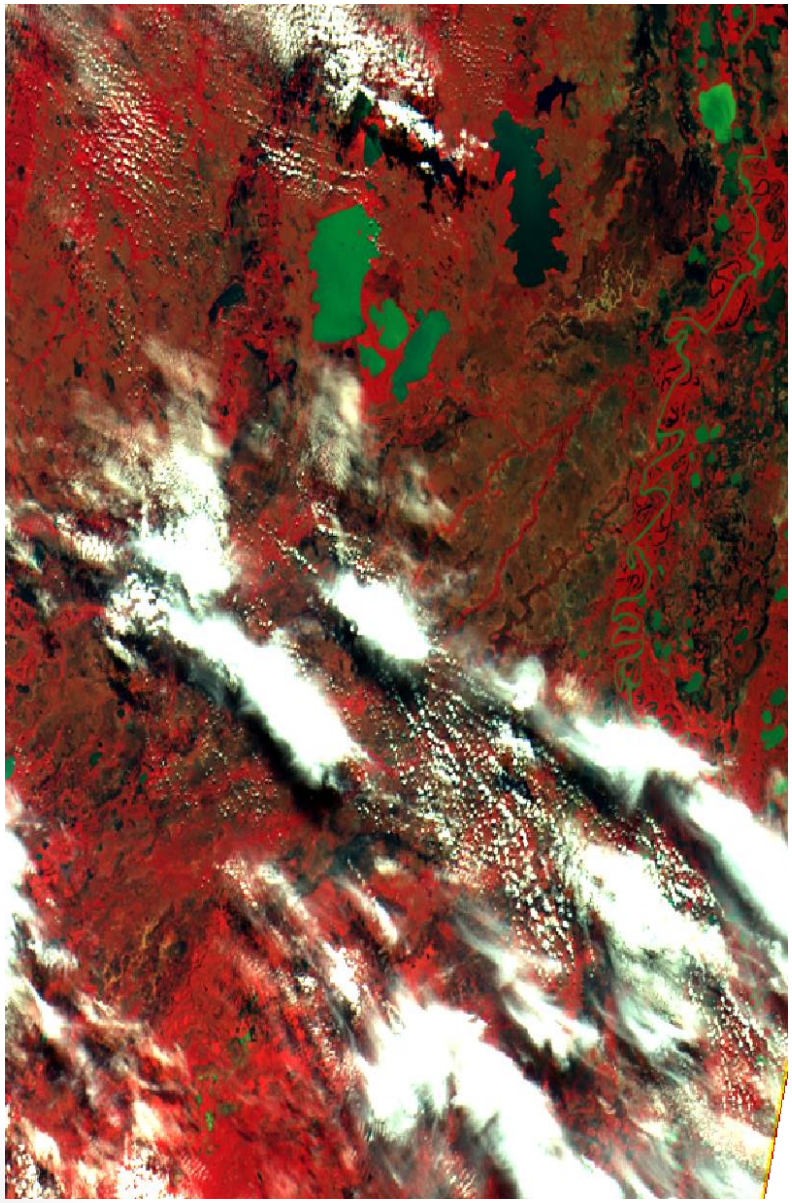

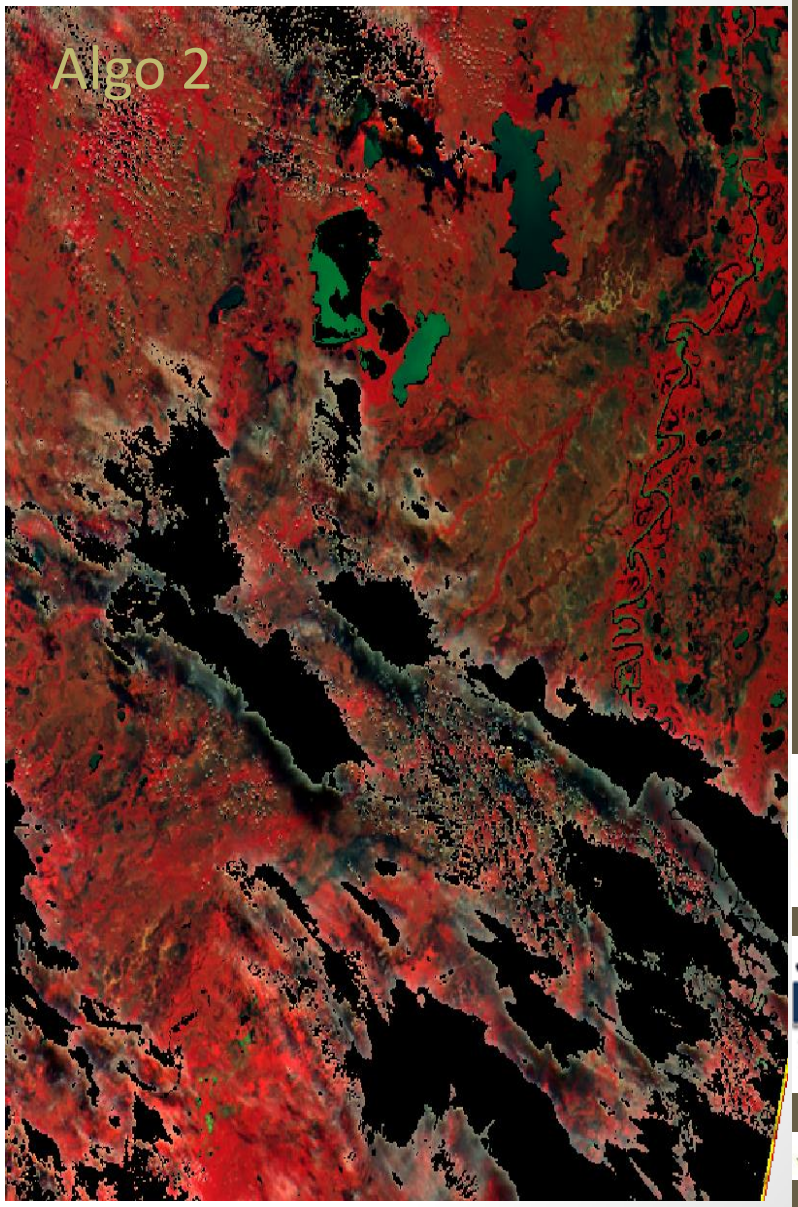

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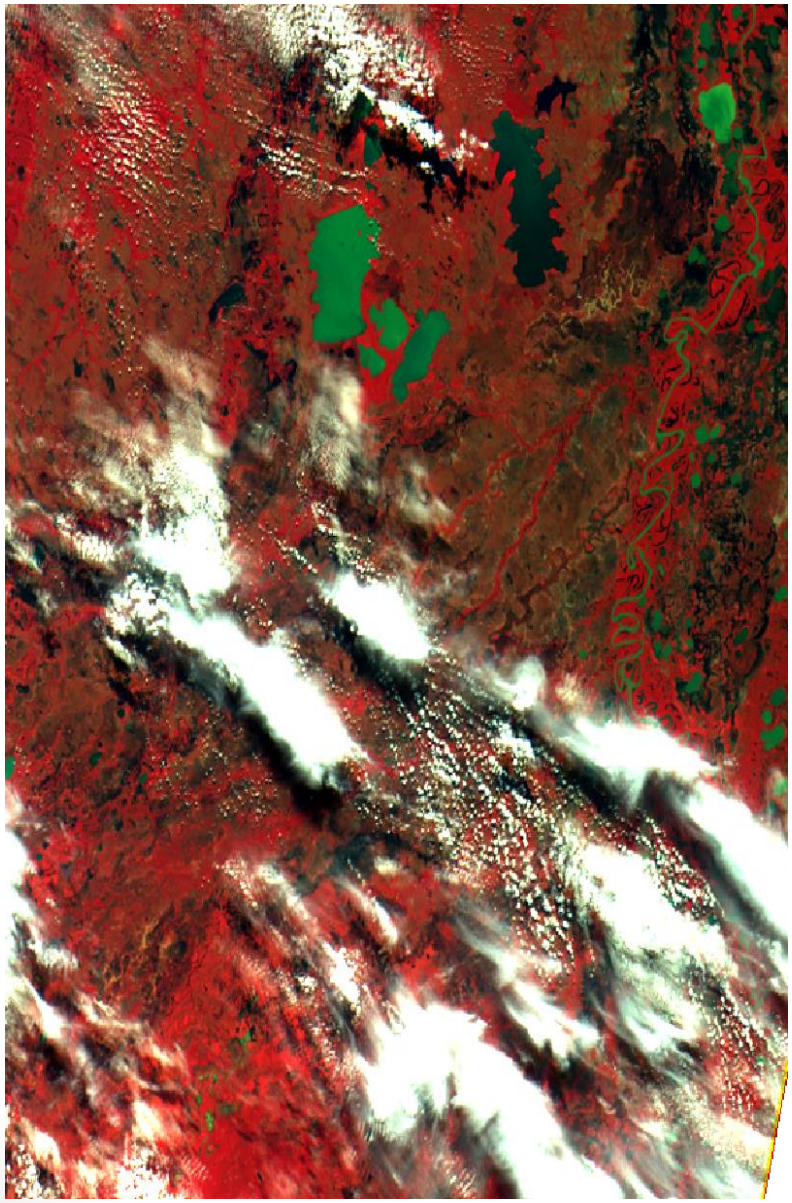

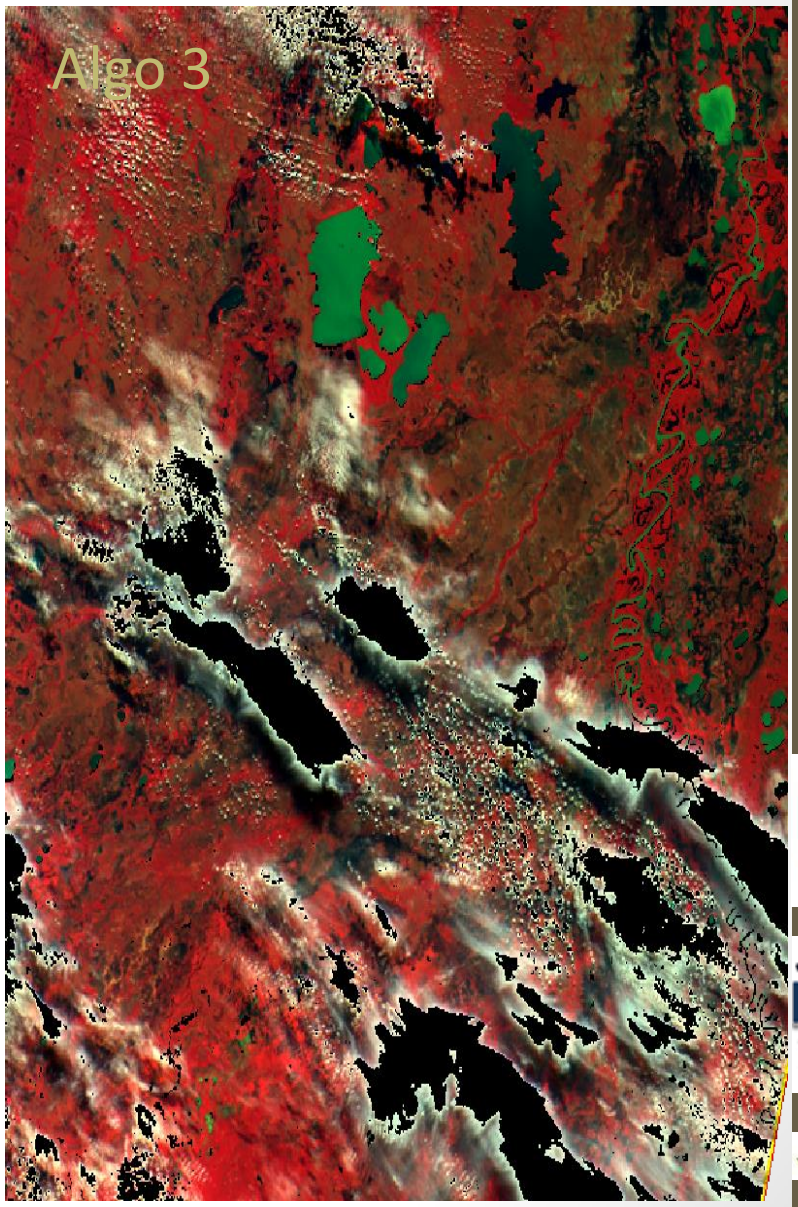

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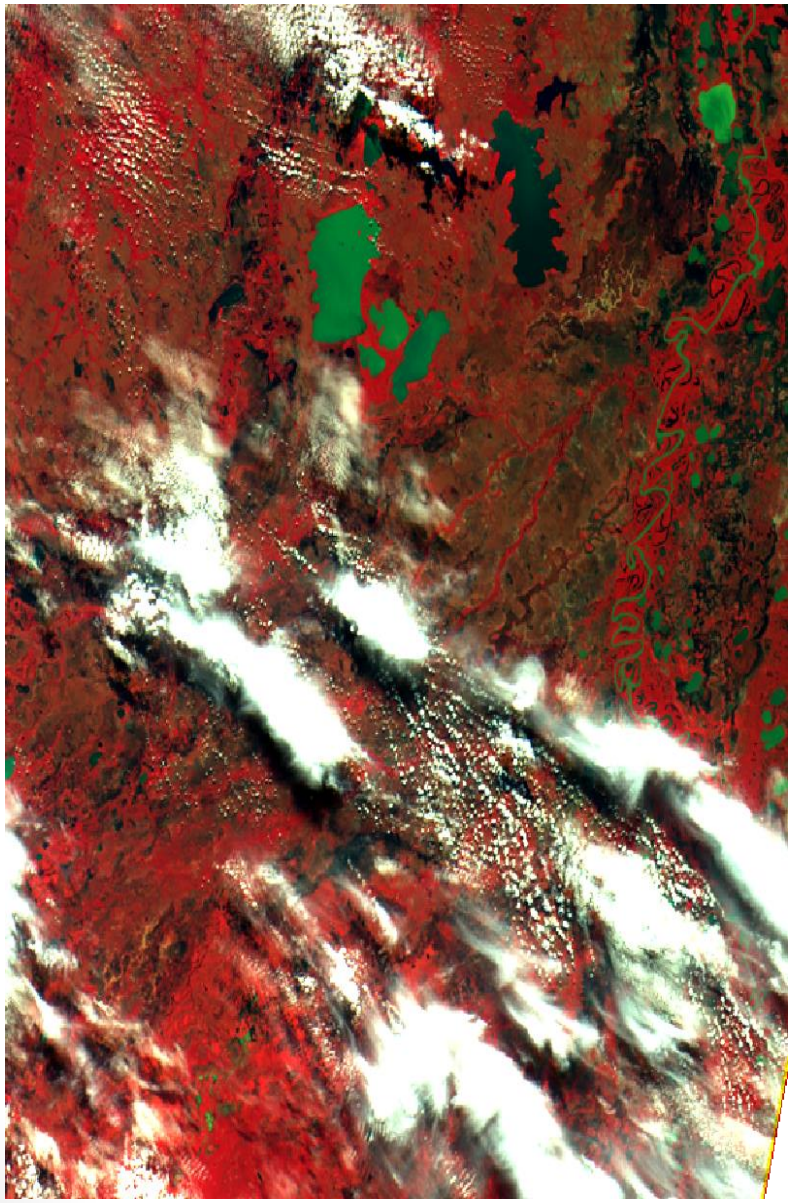

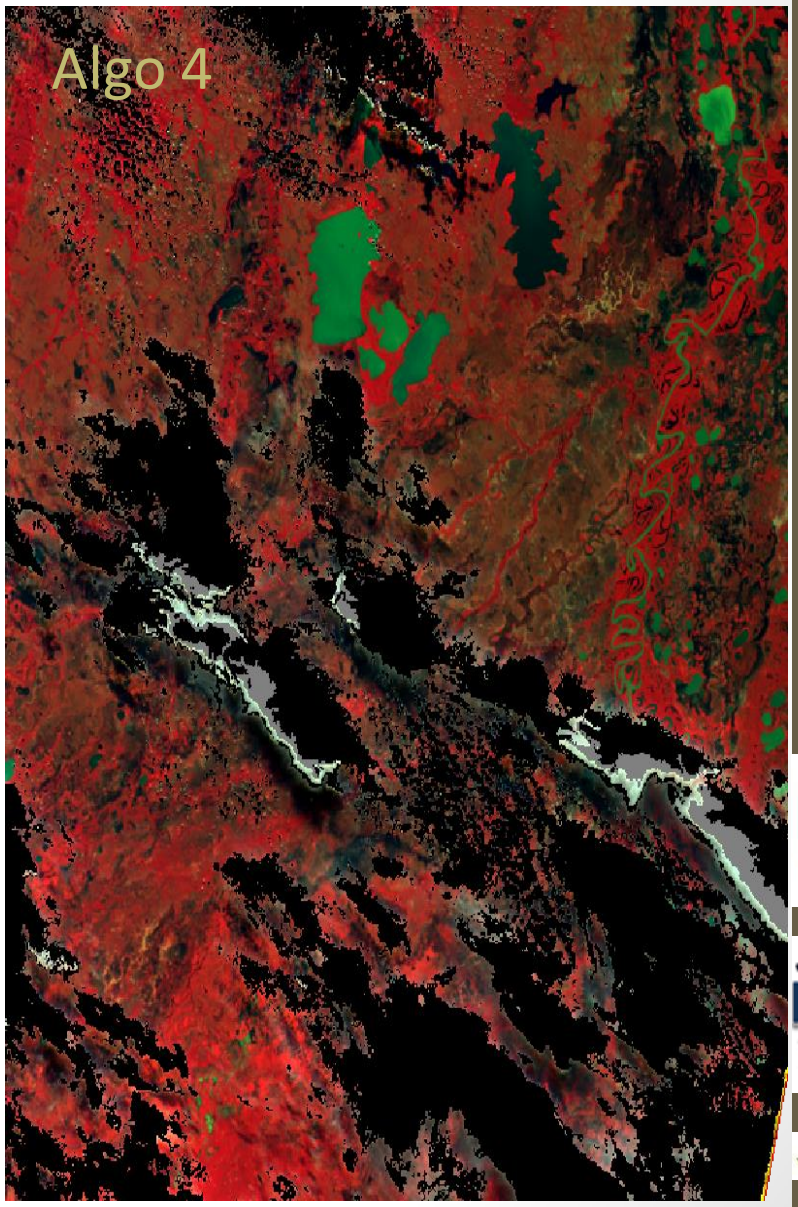

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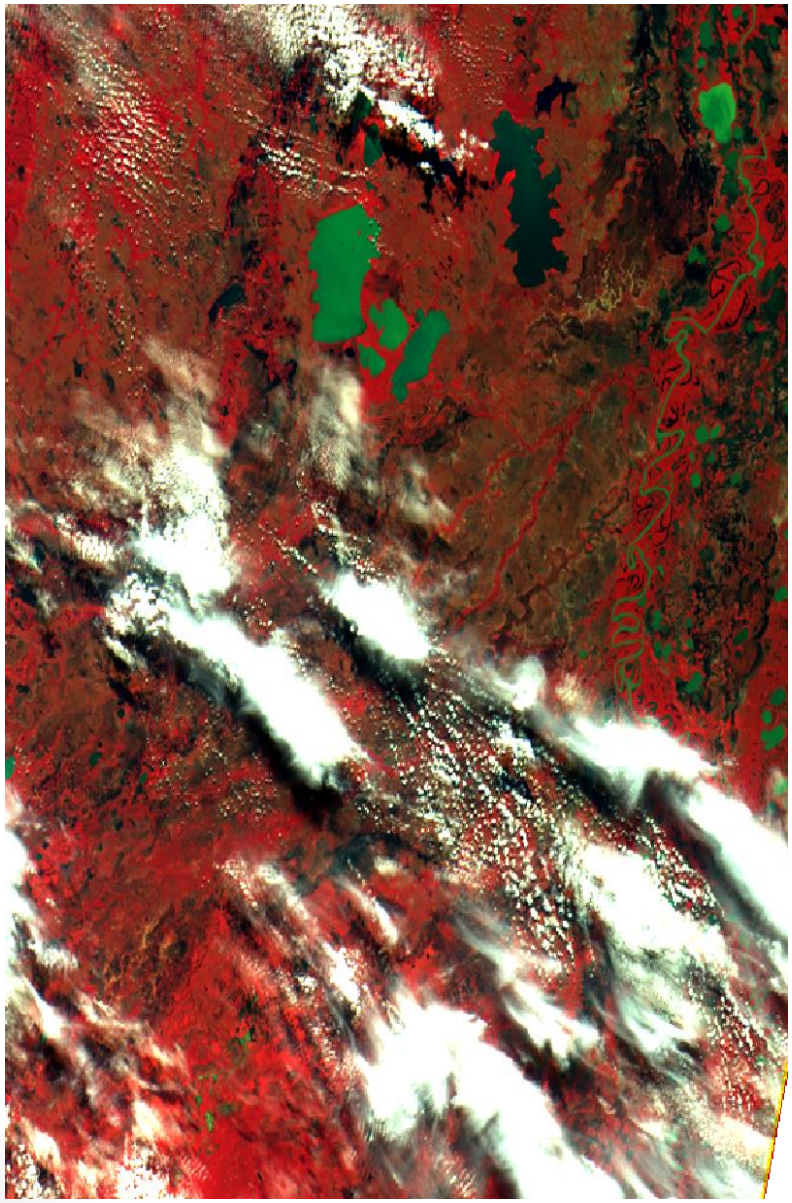

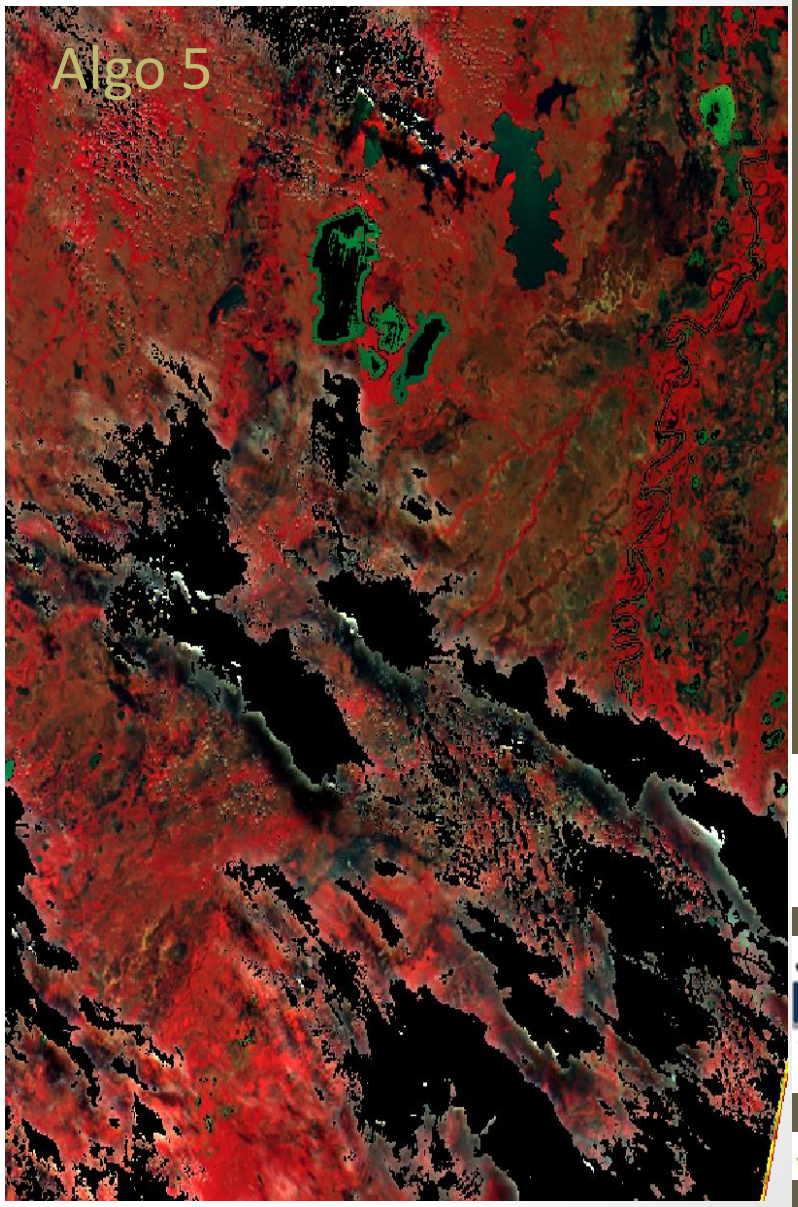

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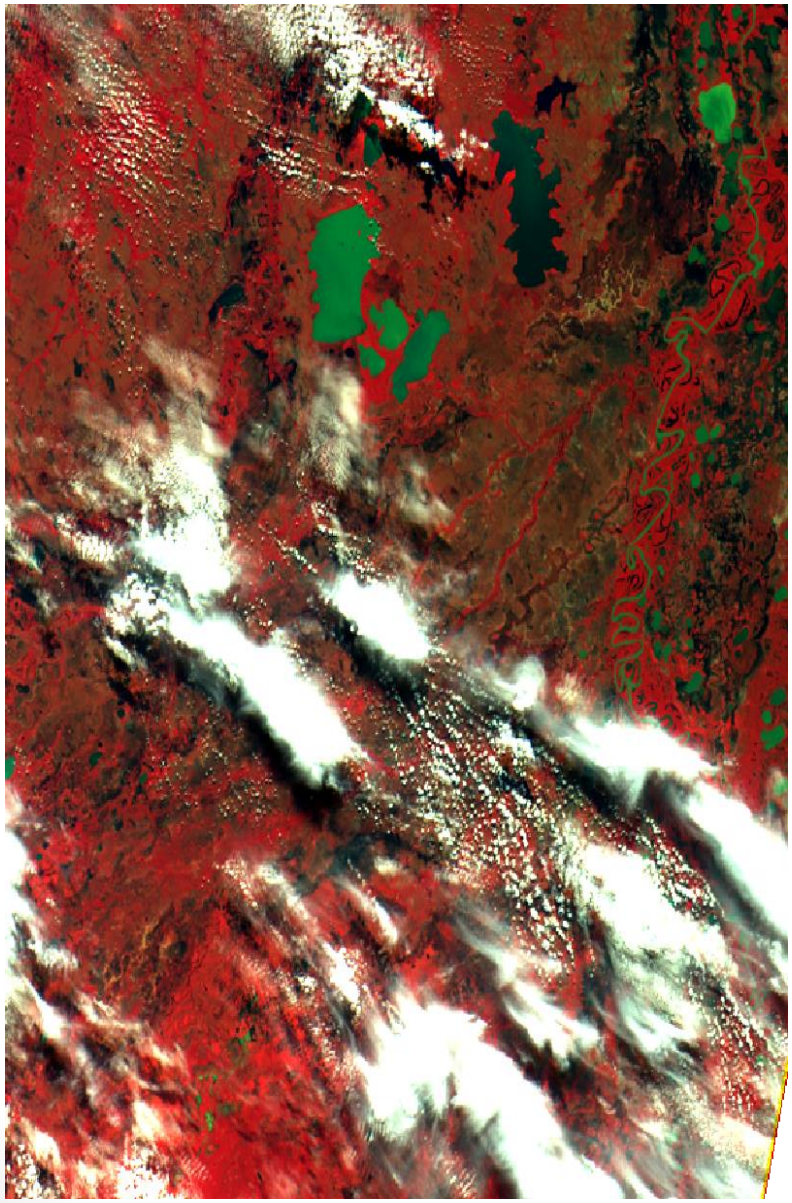

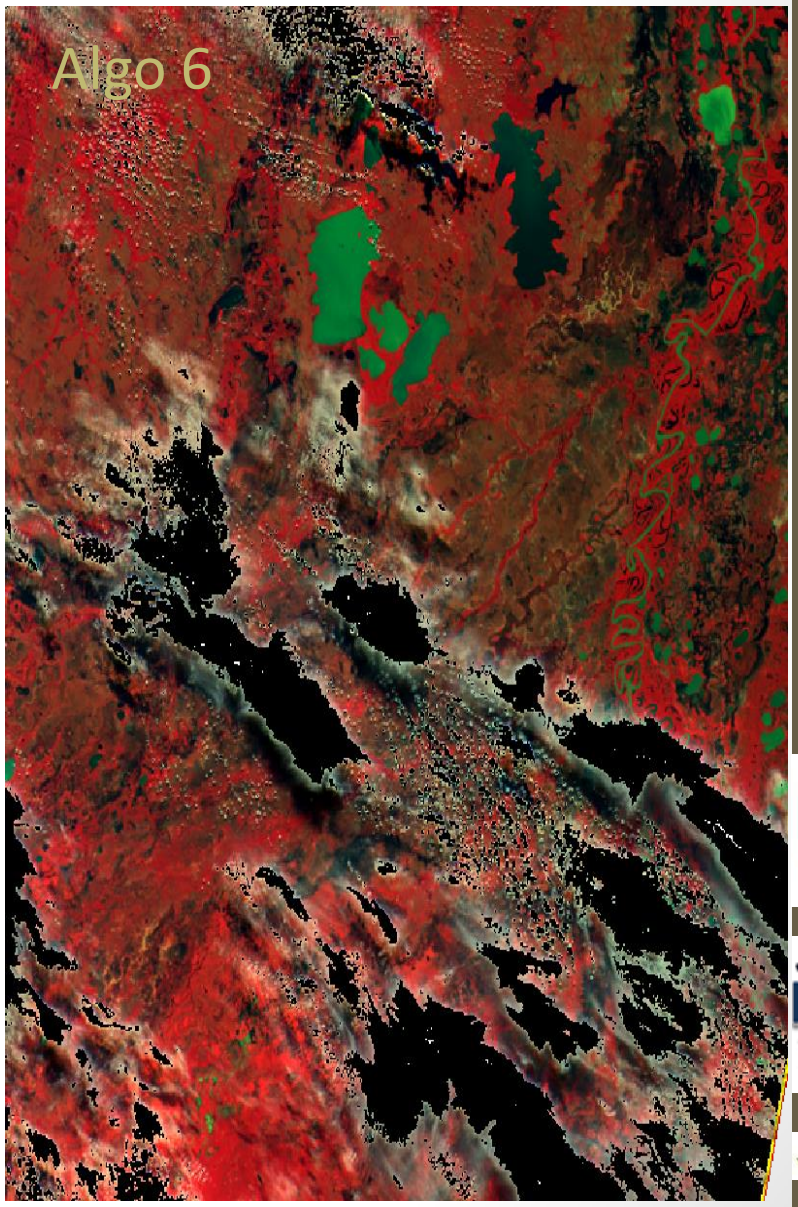

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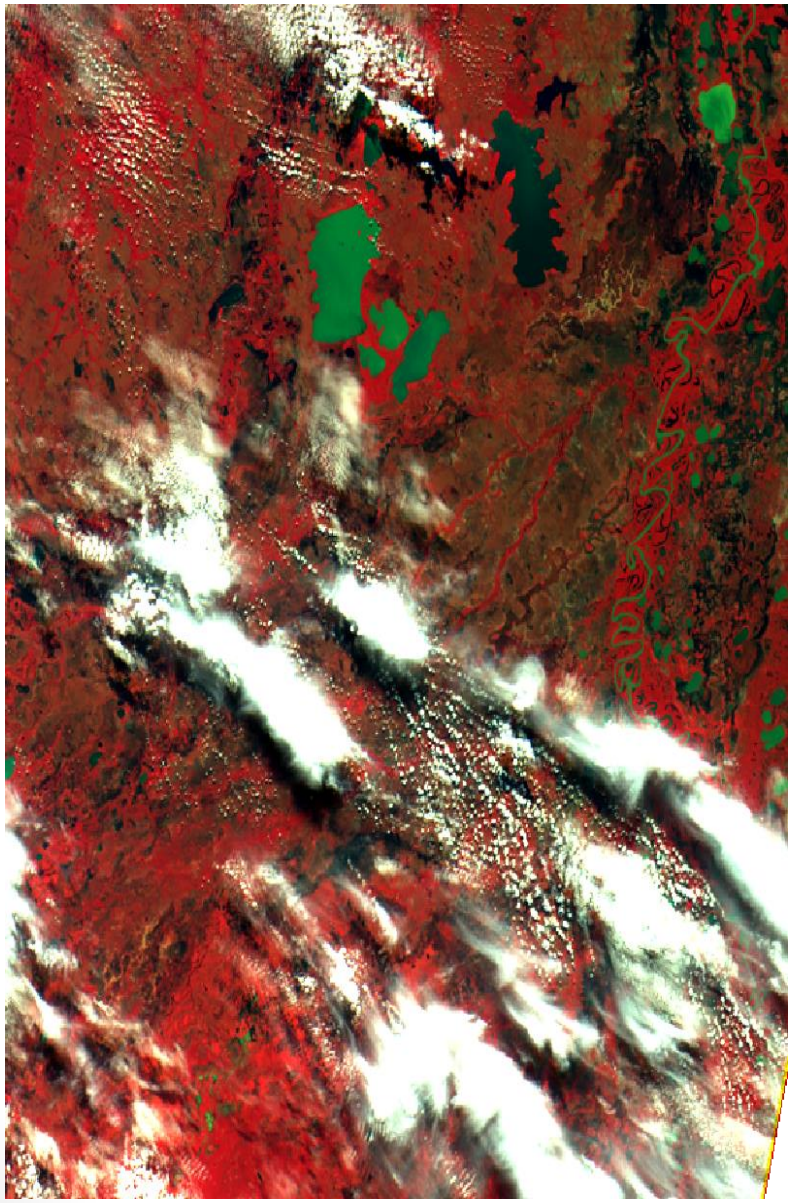

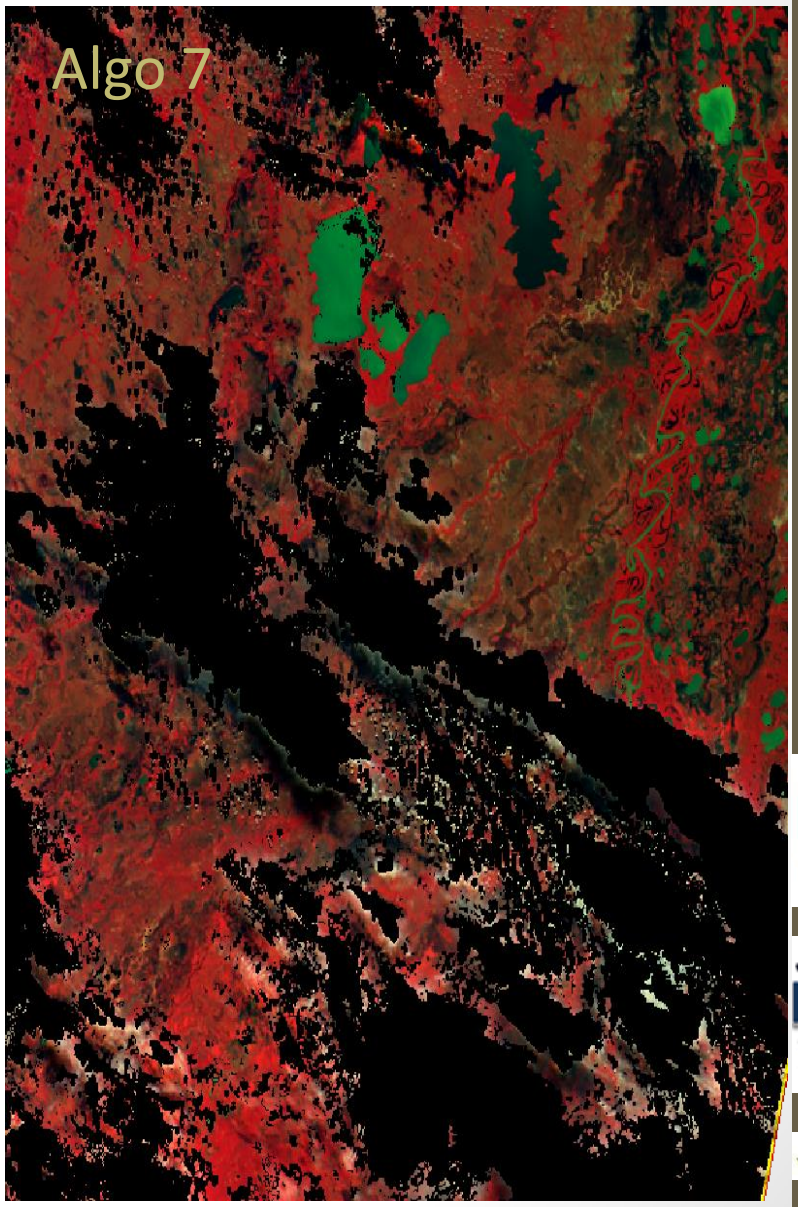

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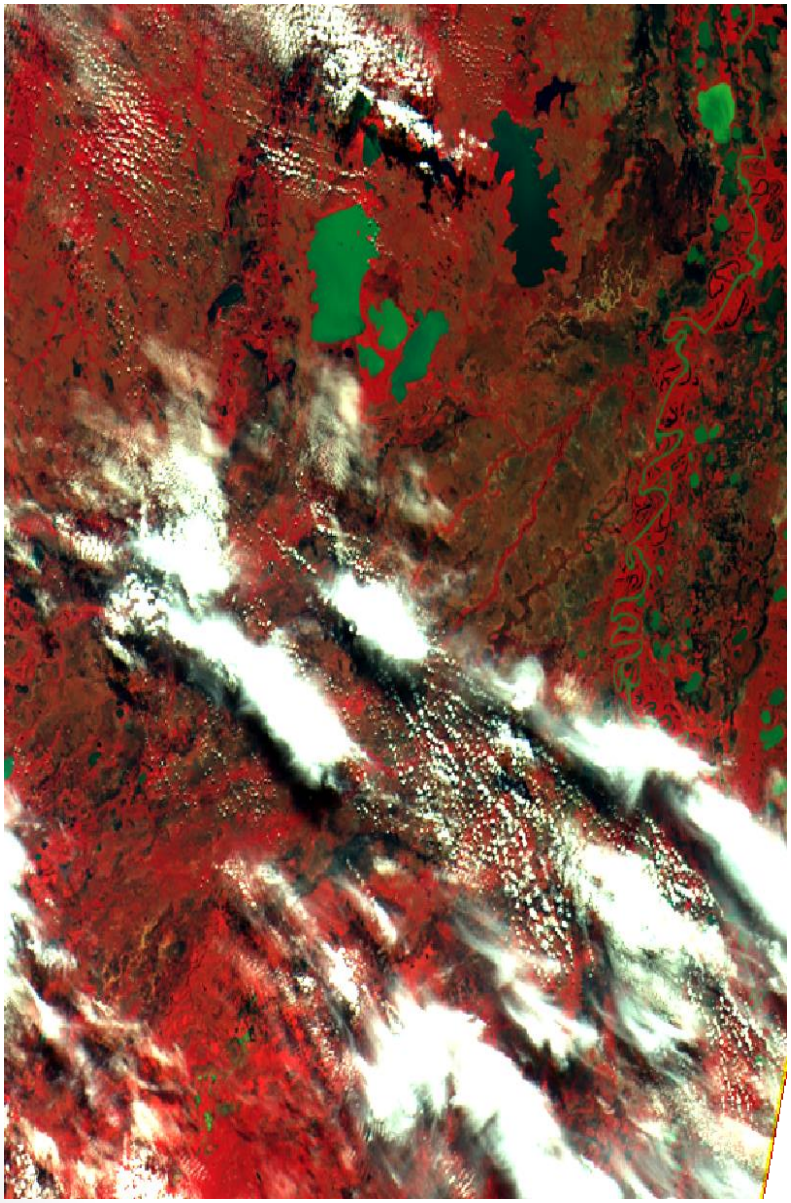
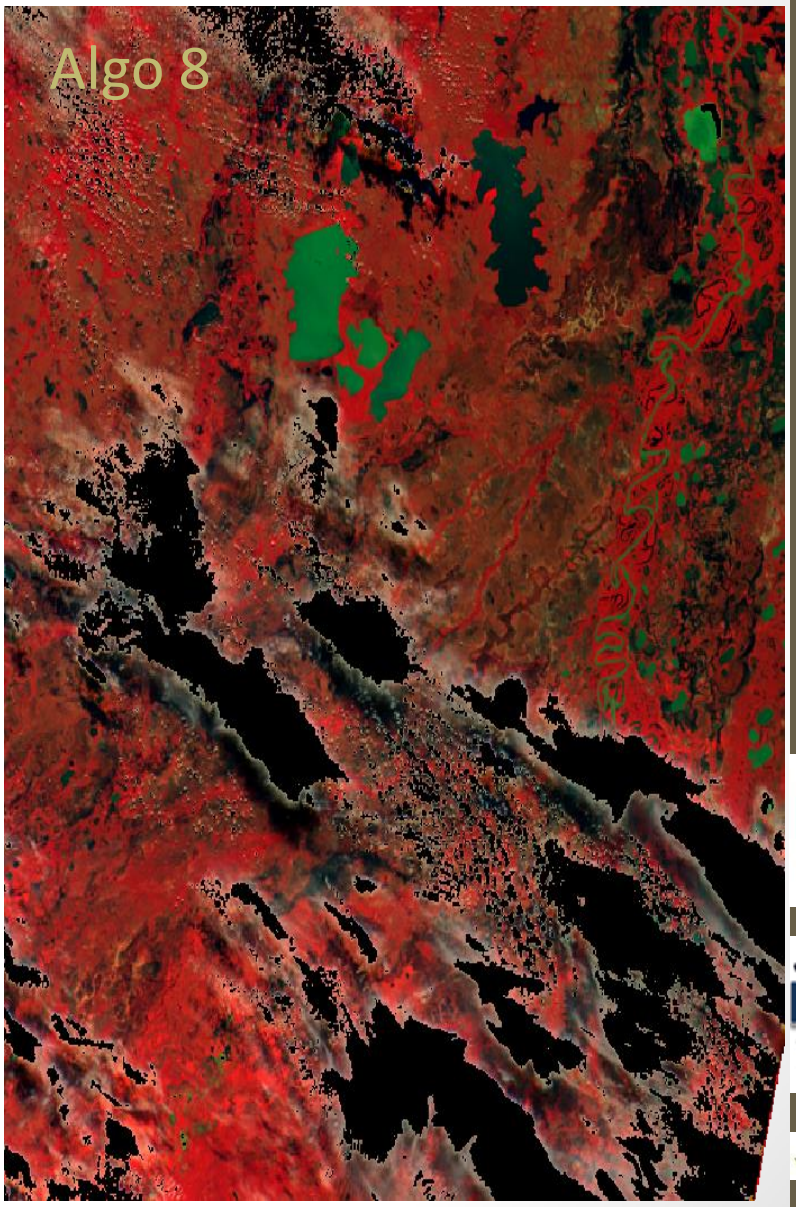
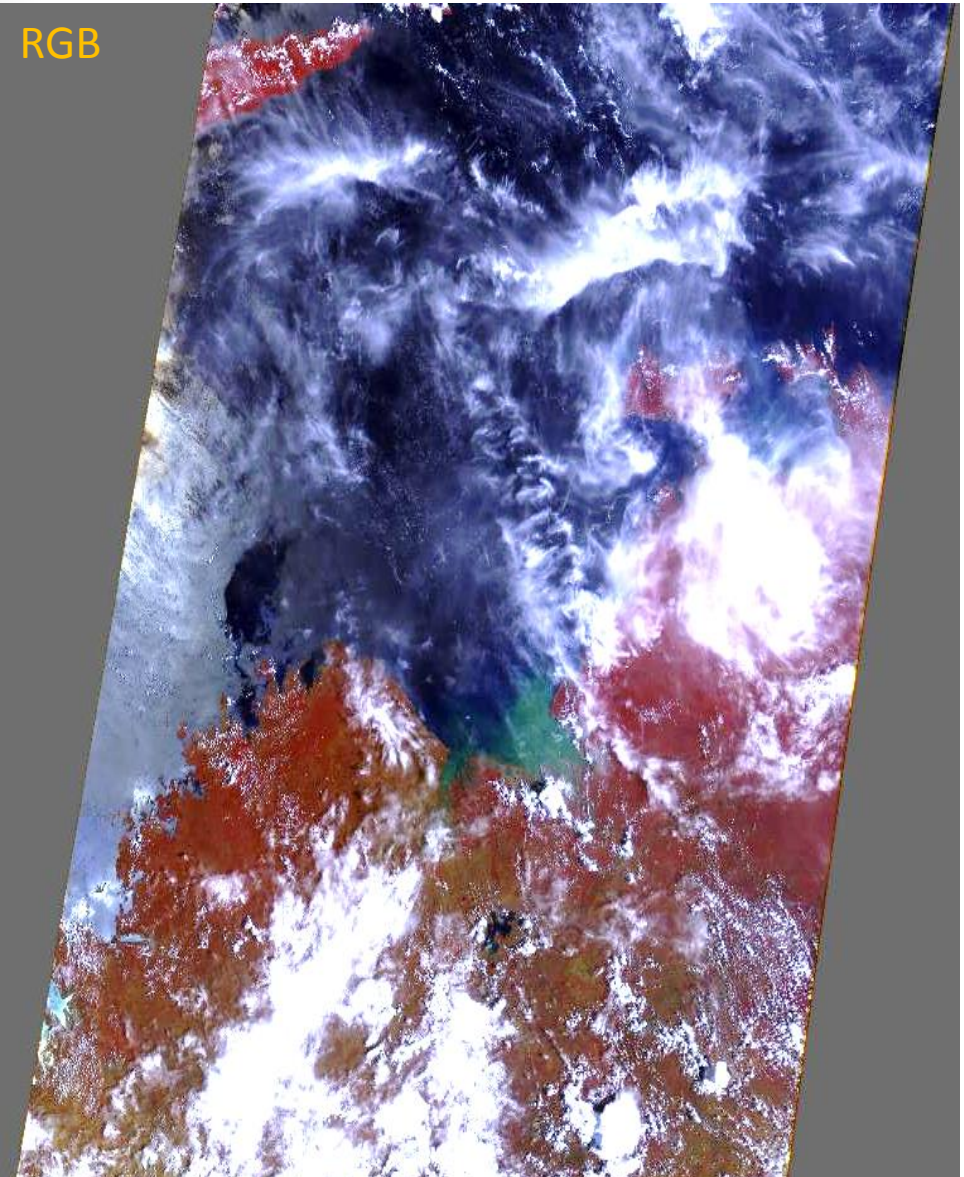
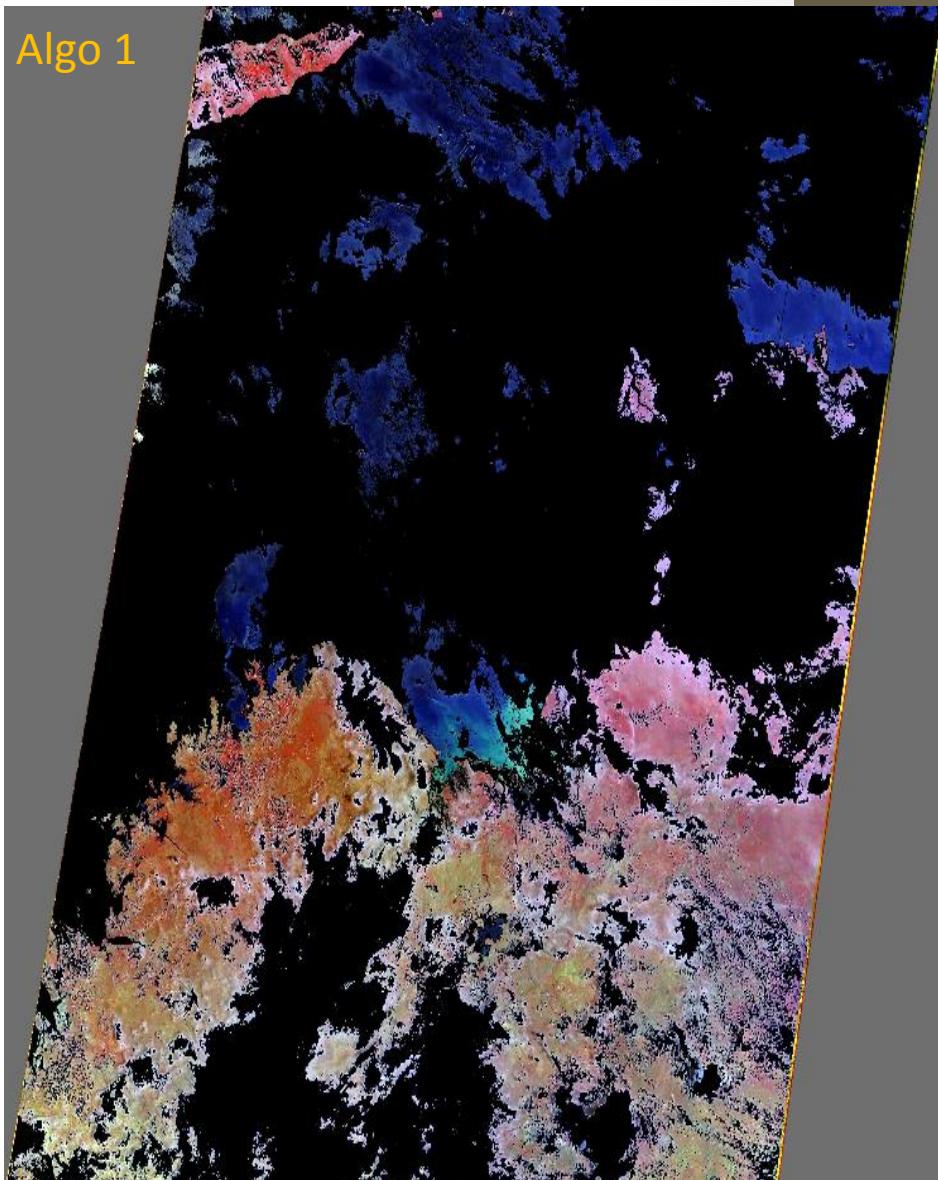




Assessment – Cloud over clear water, turbid water, small clouds over land, semi-transparent clouds, sun glint





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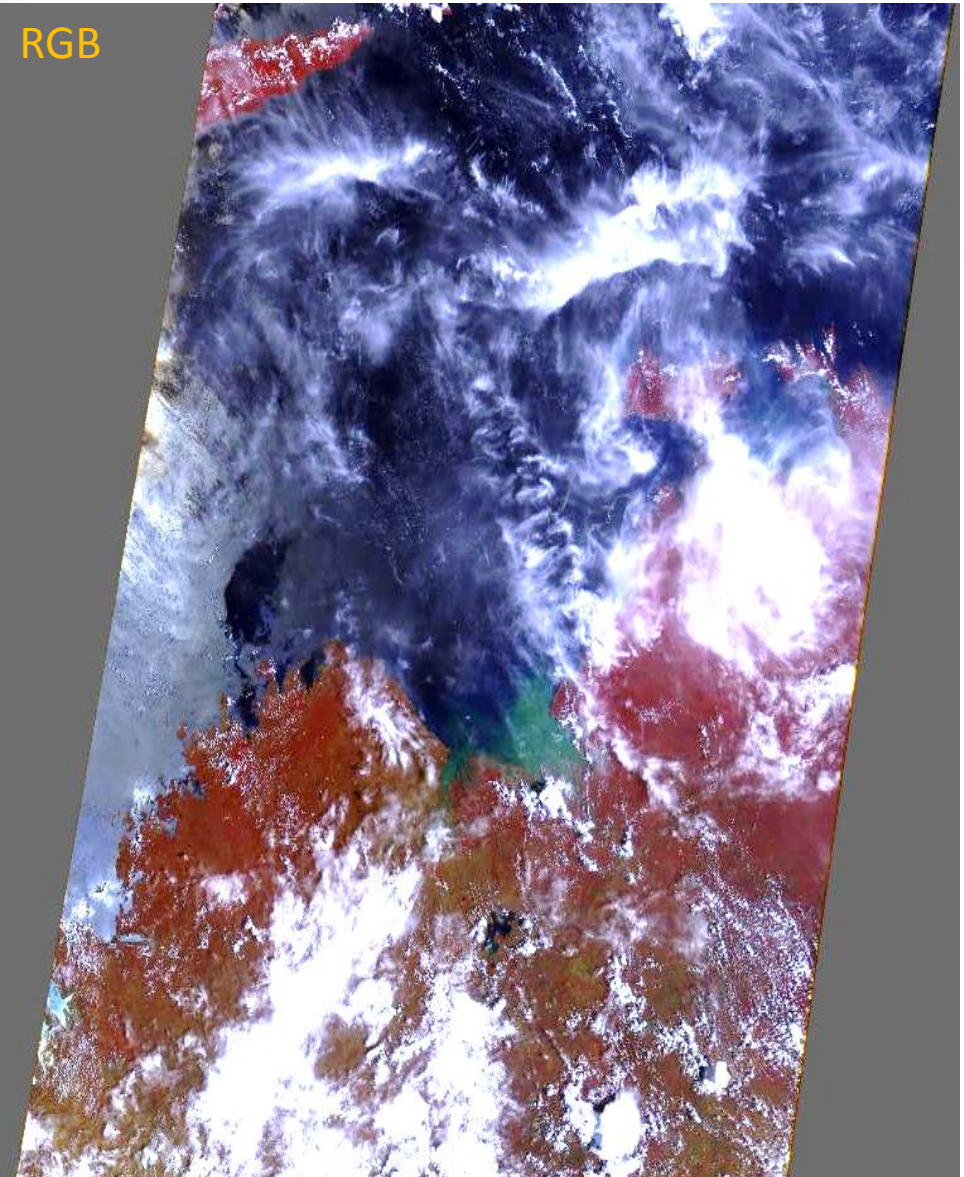

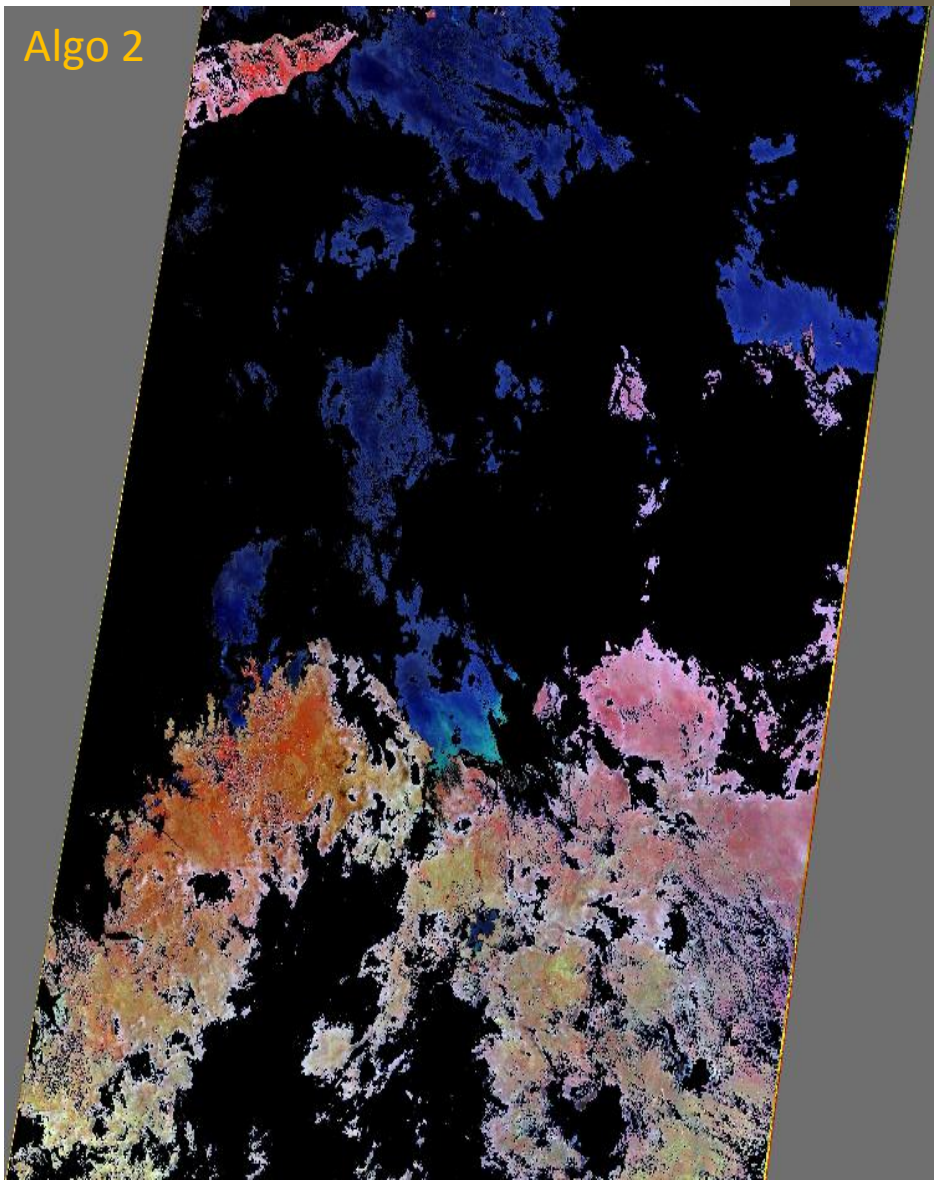

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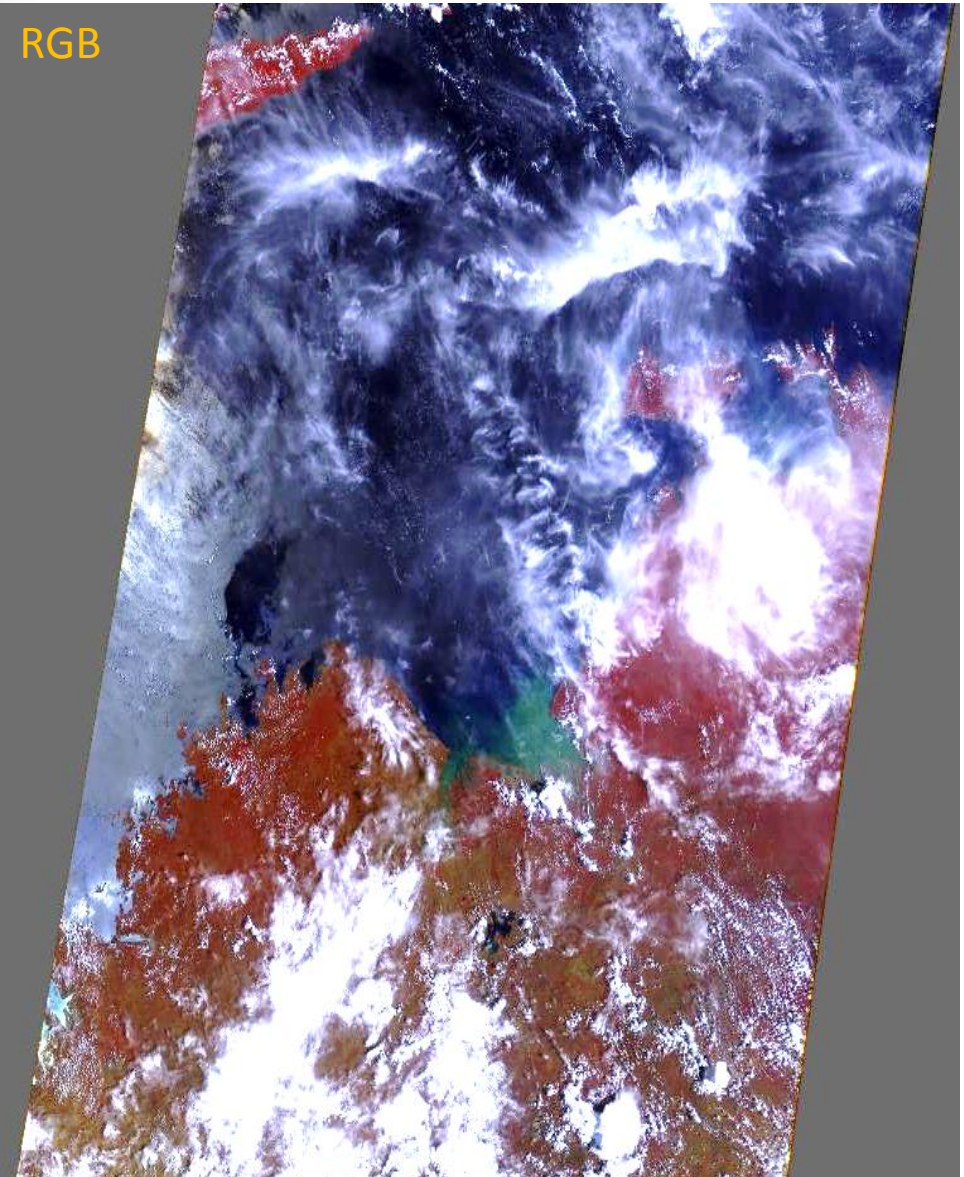

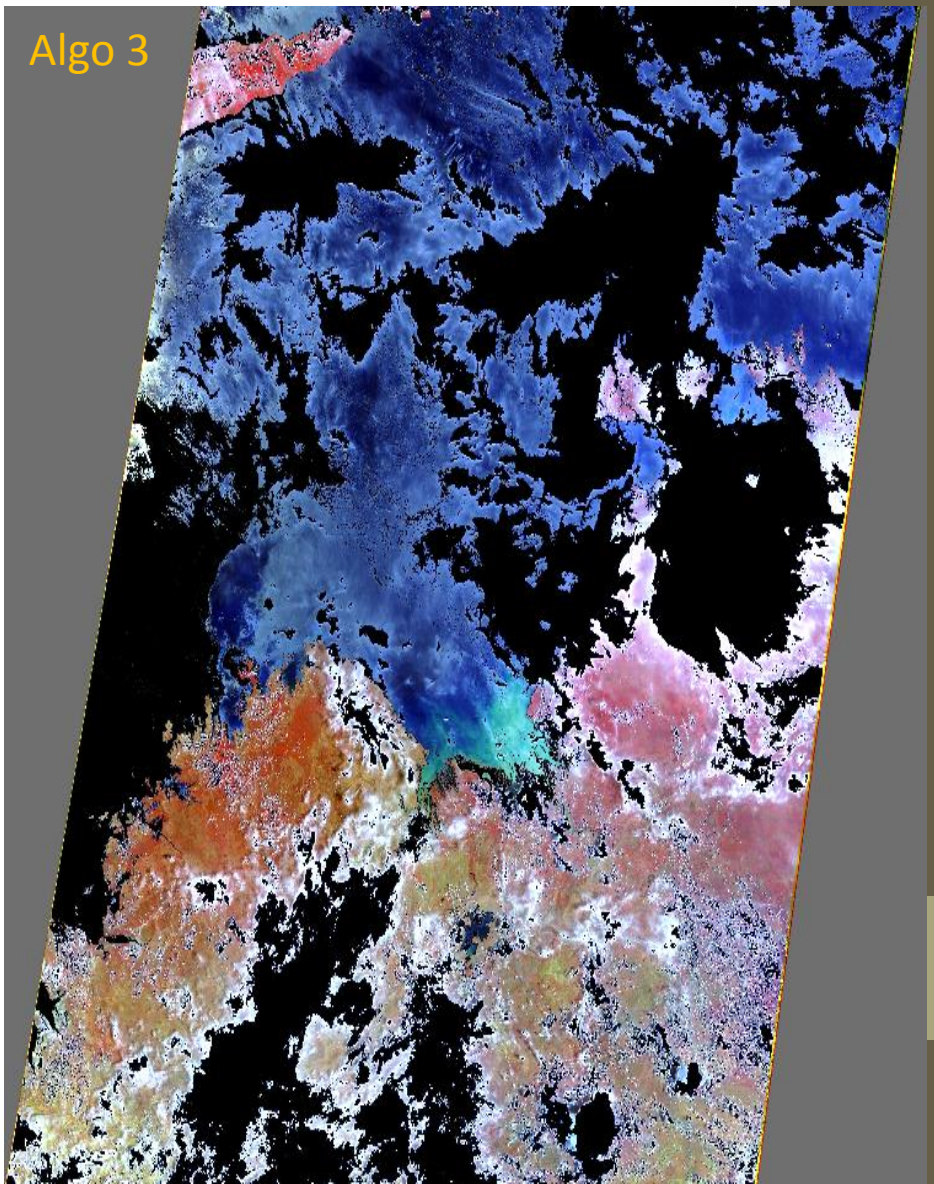

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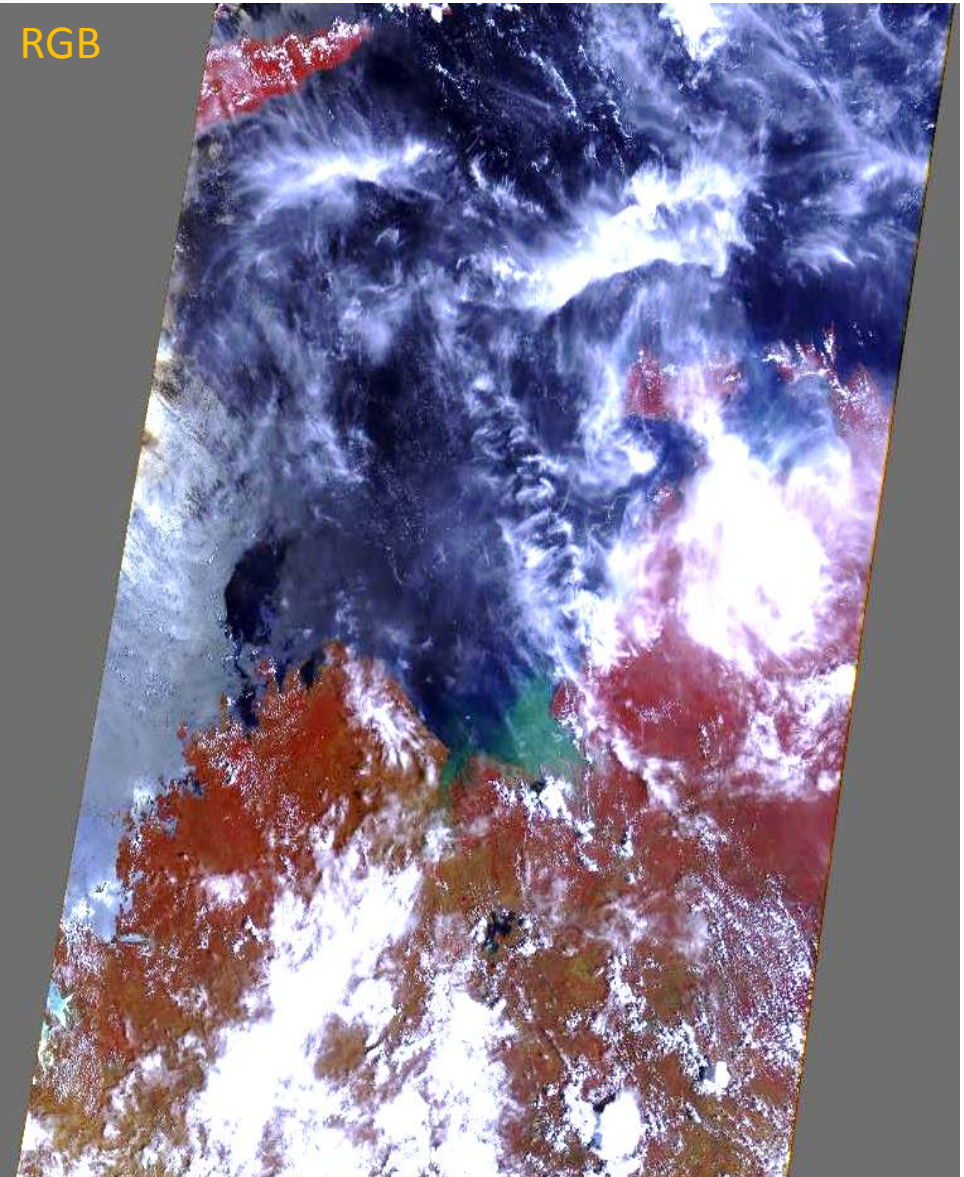

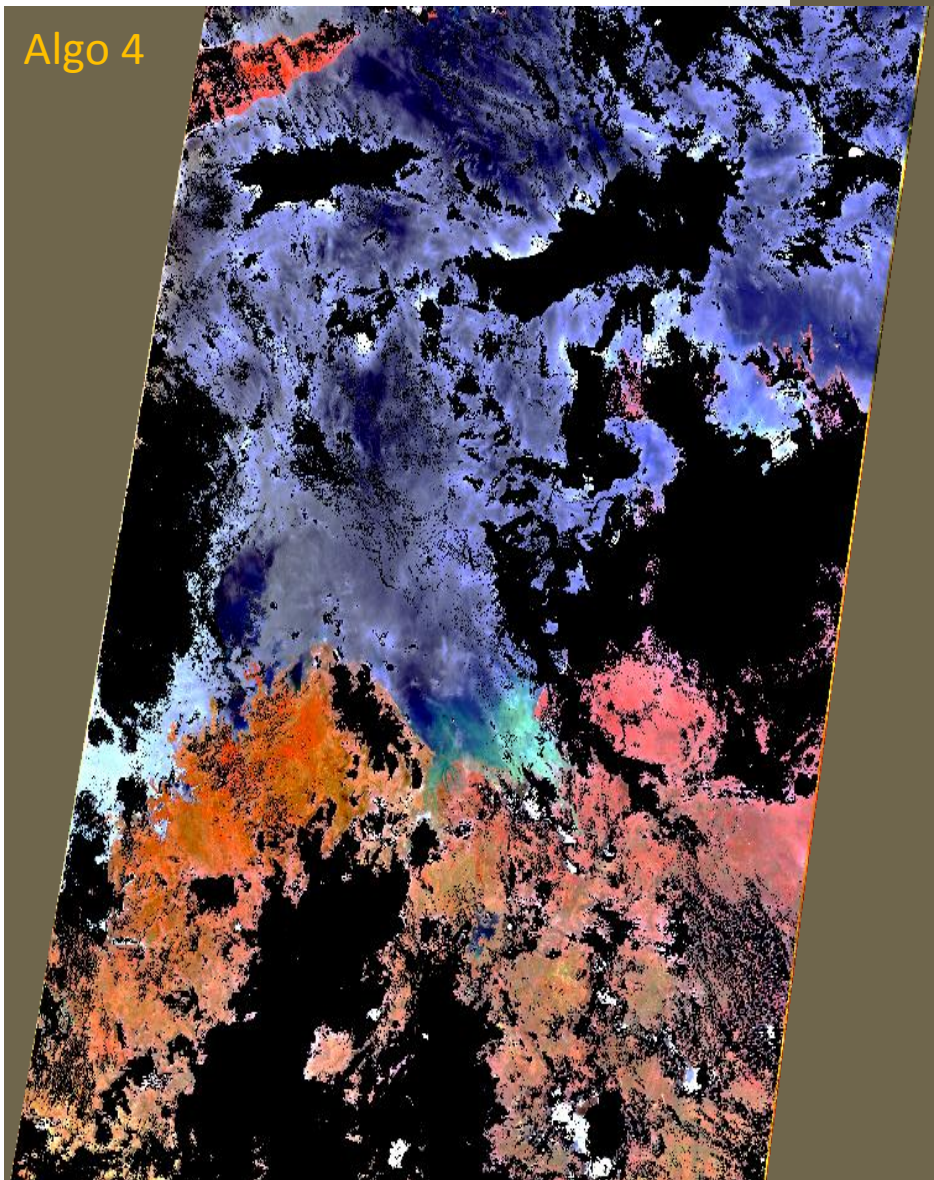

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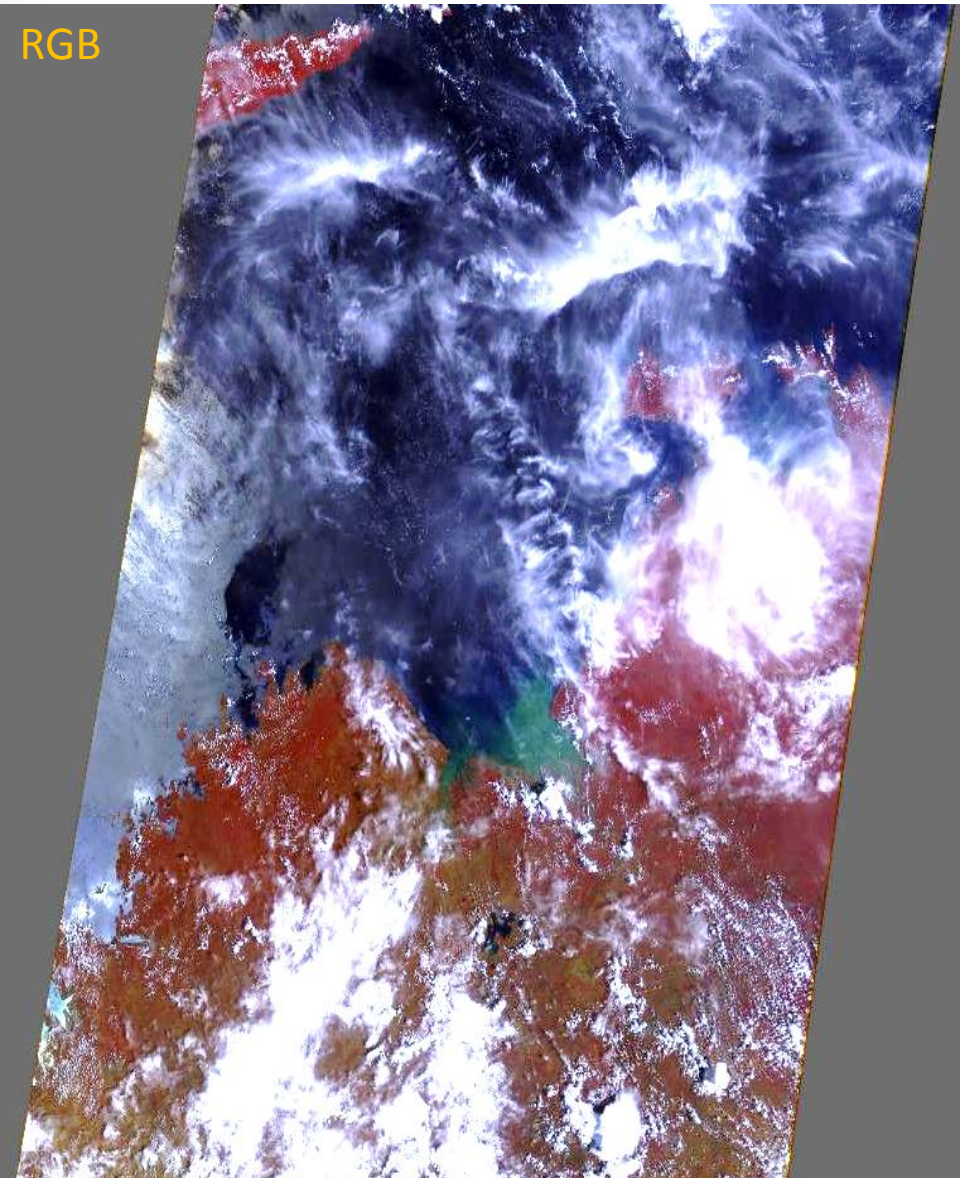

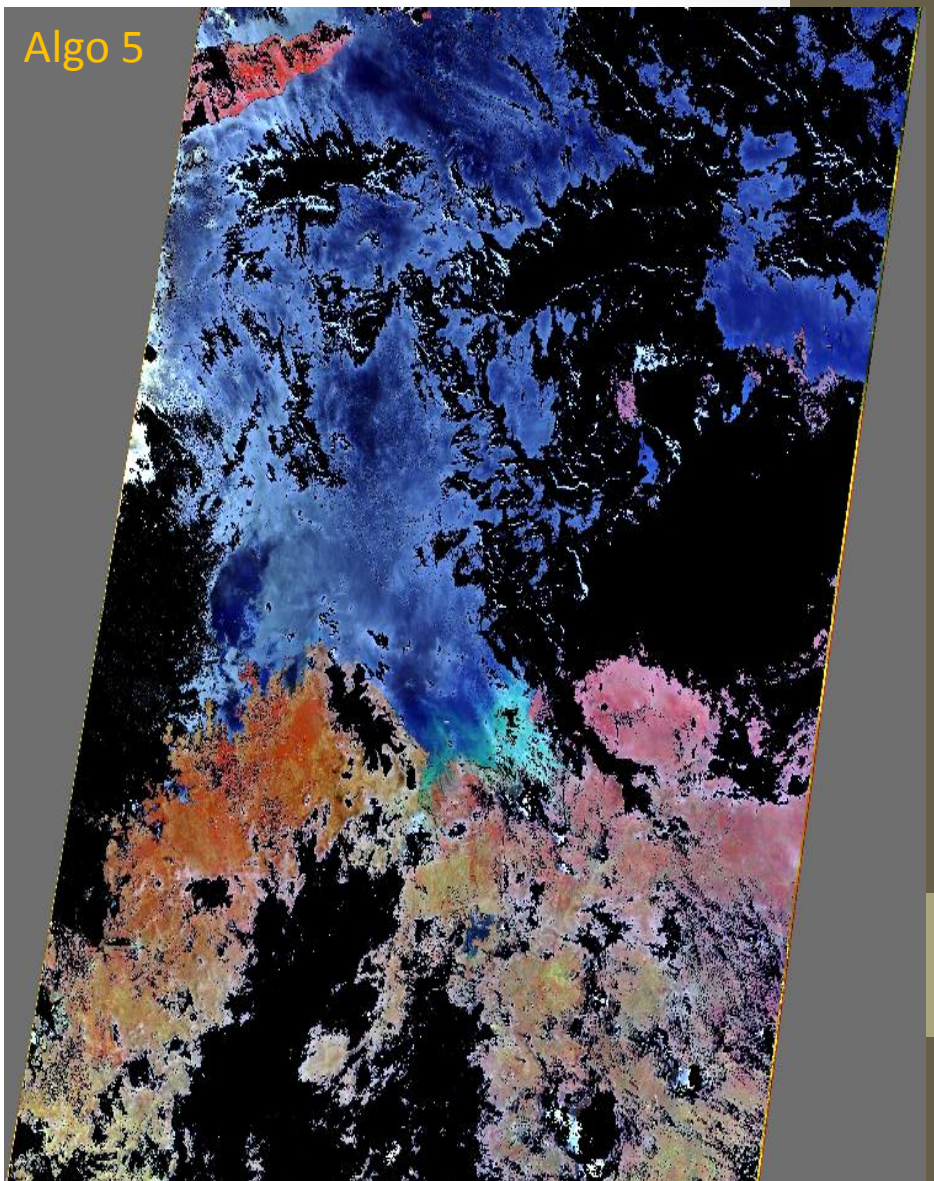

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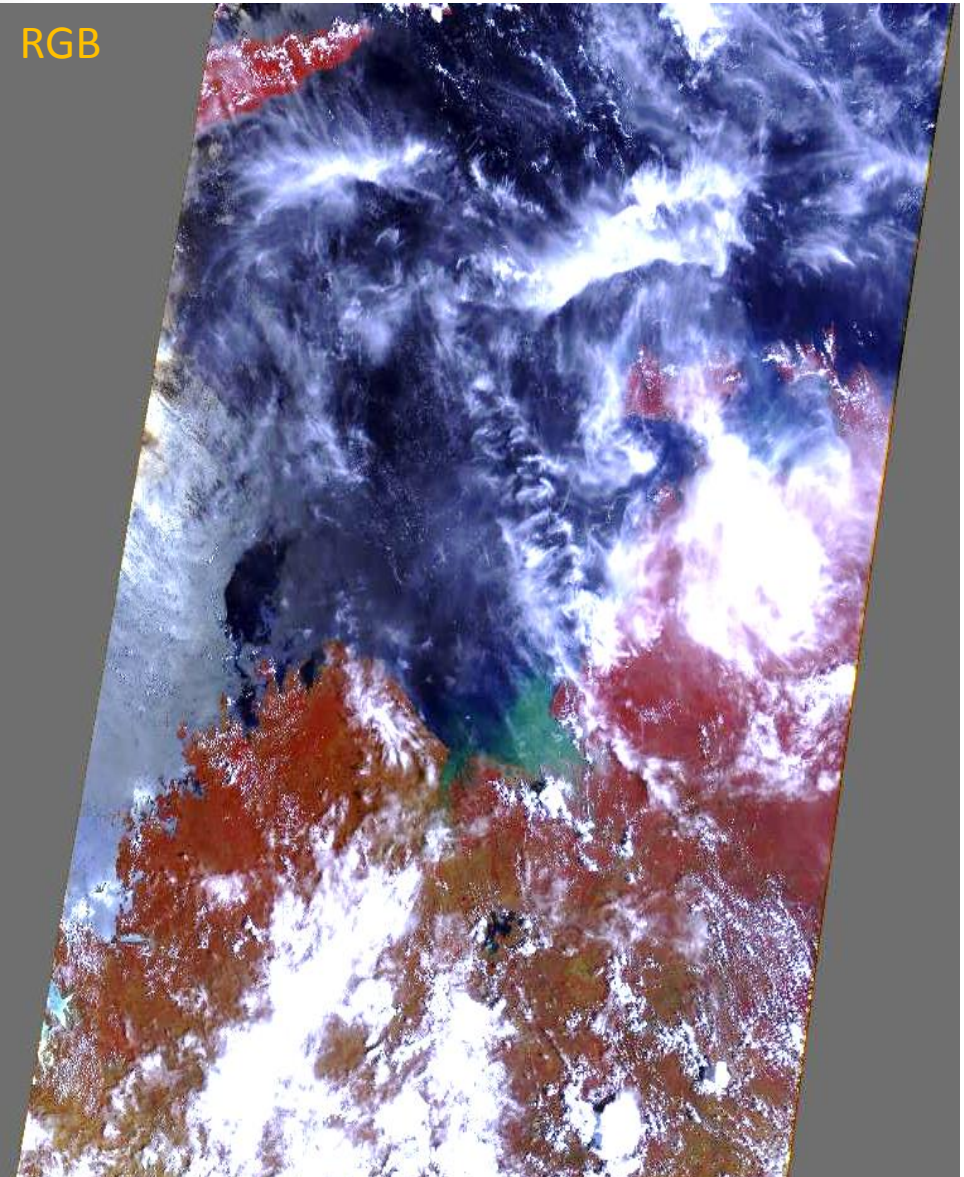

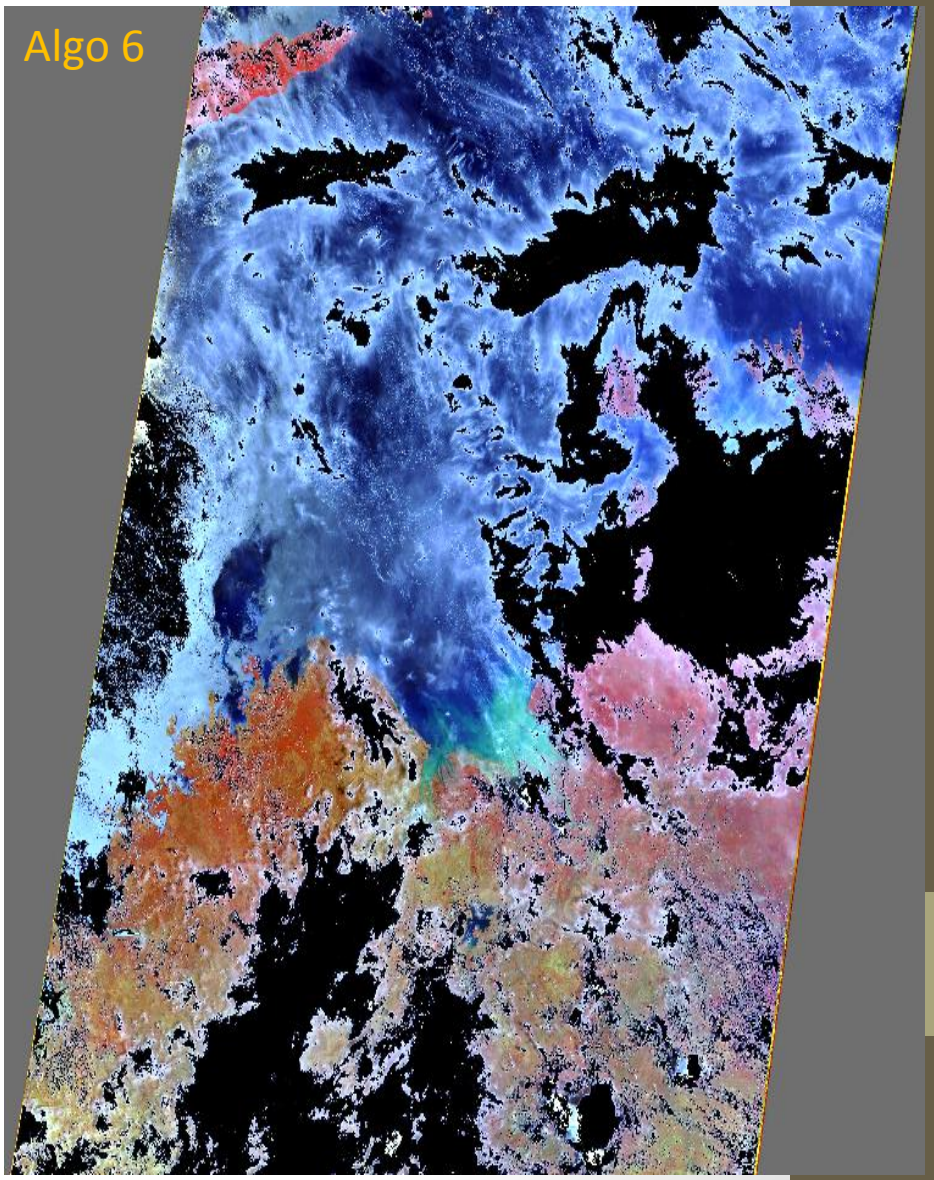

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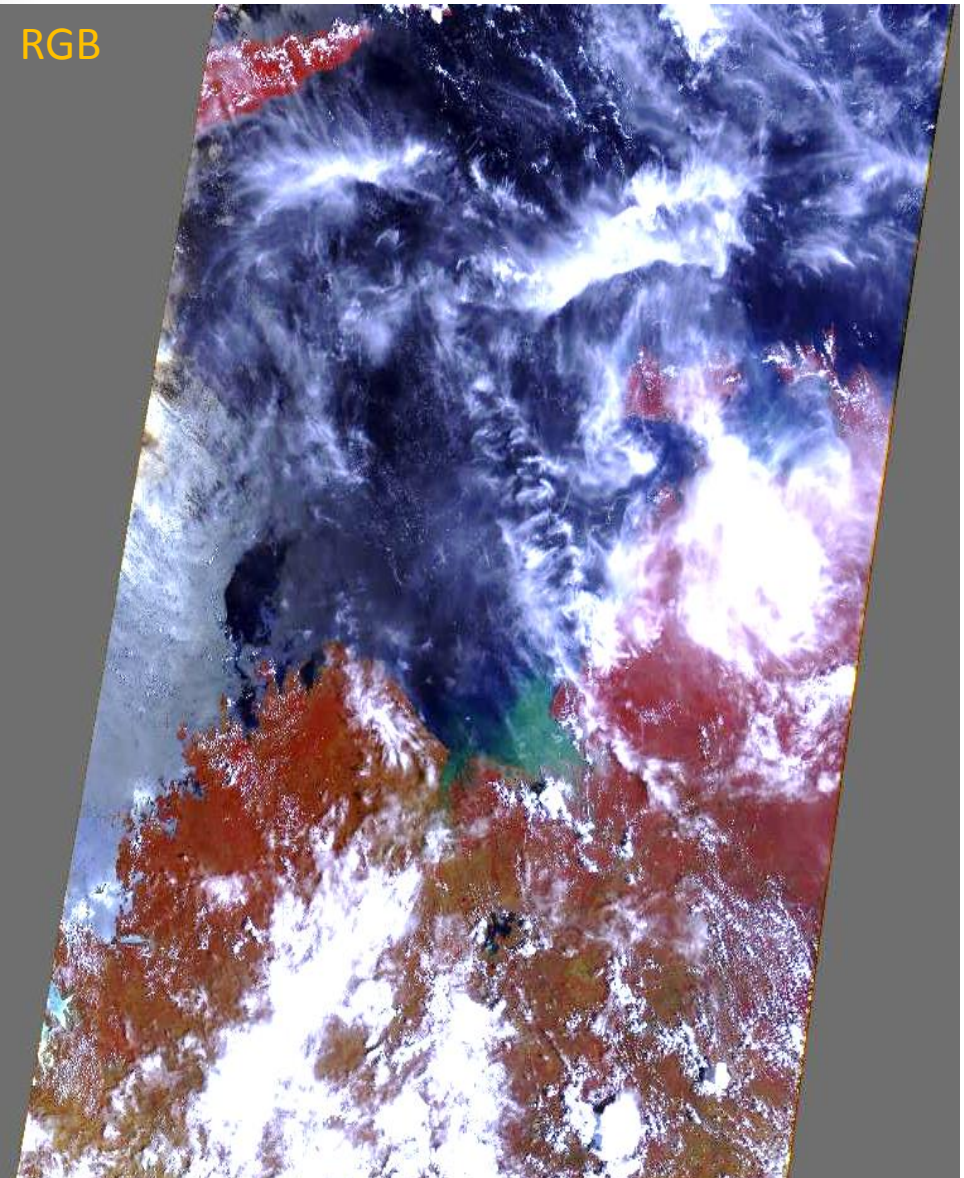

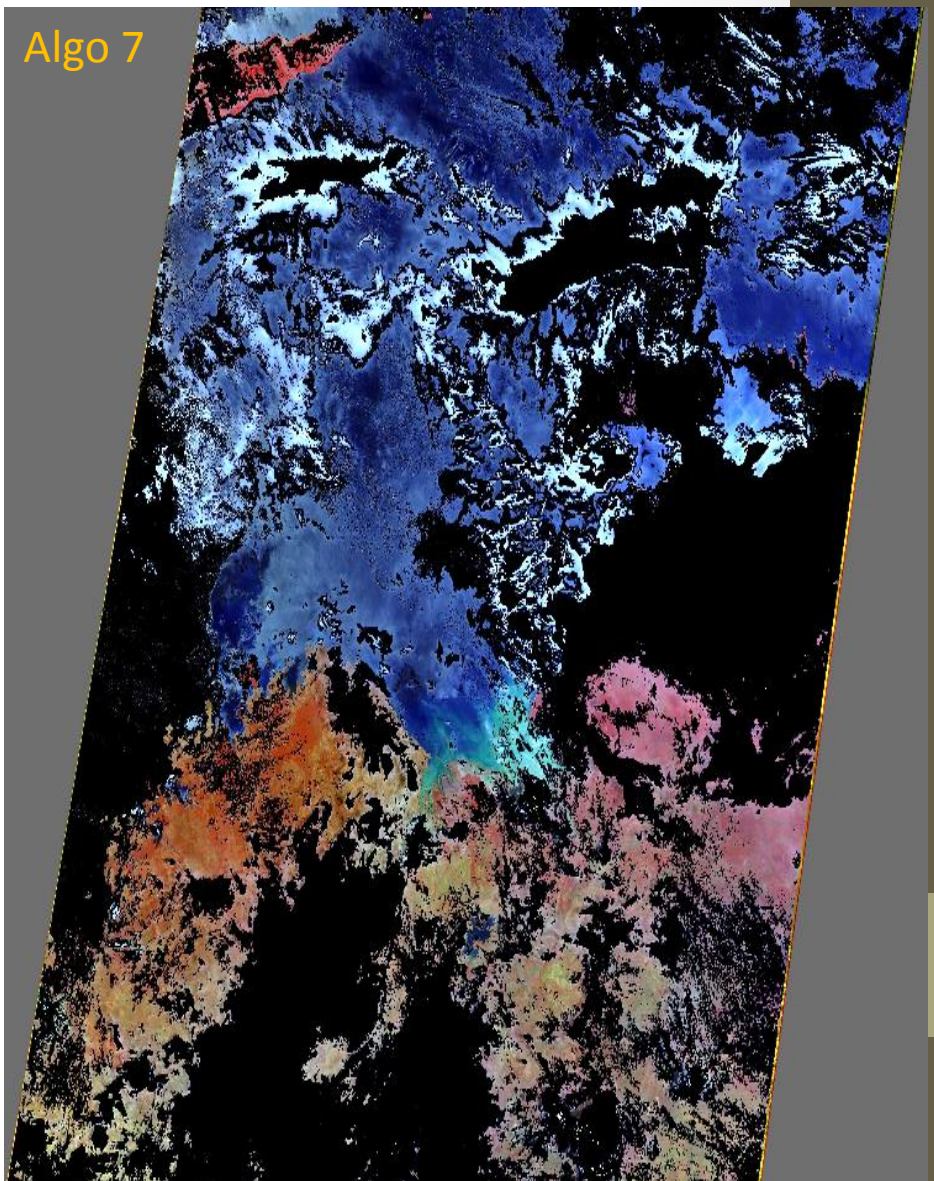

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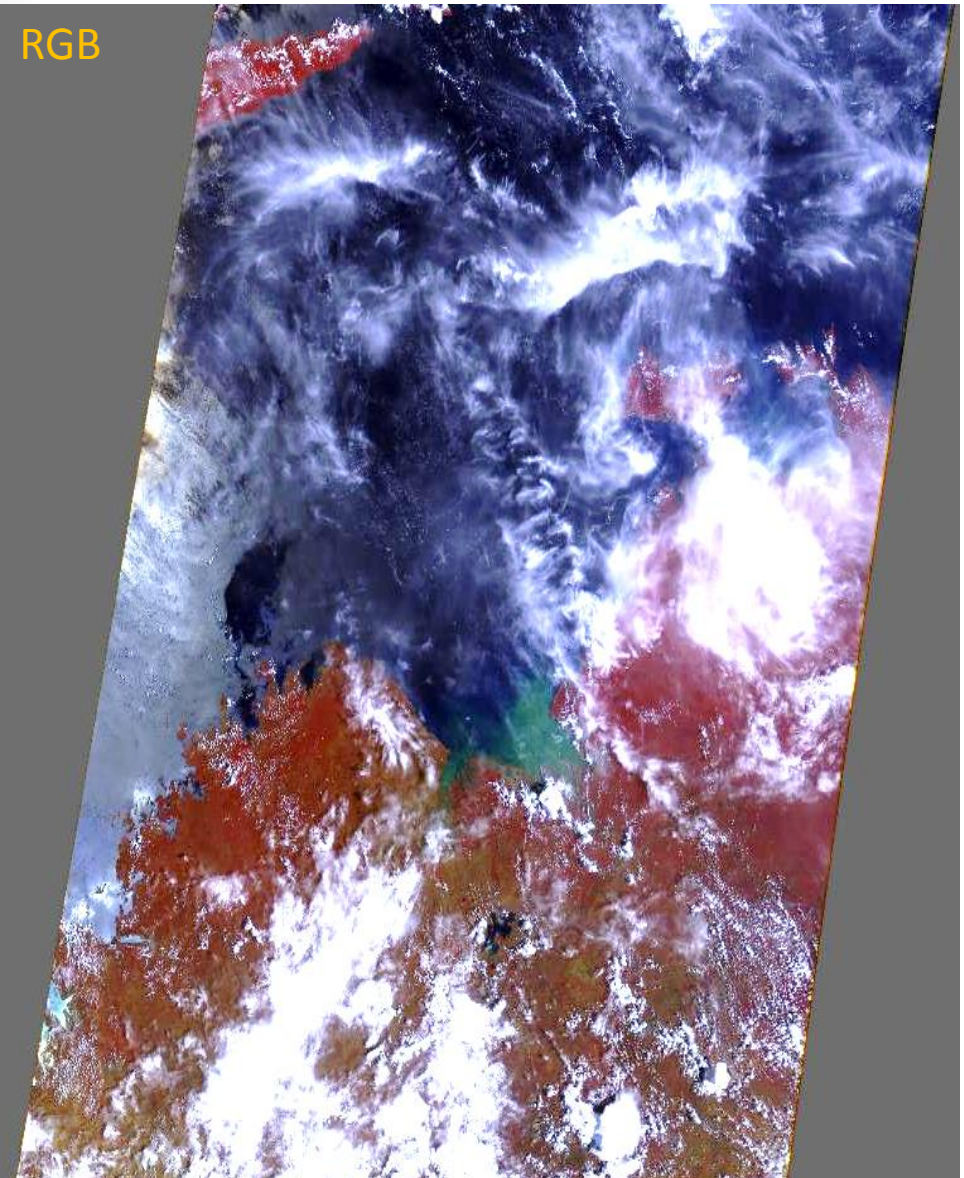
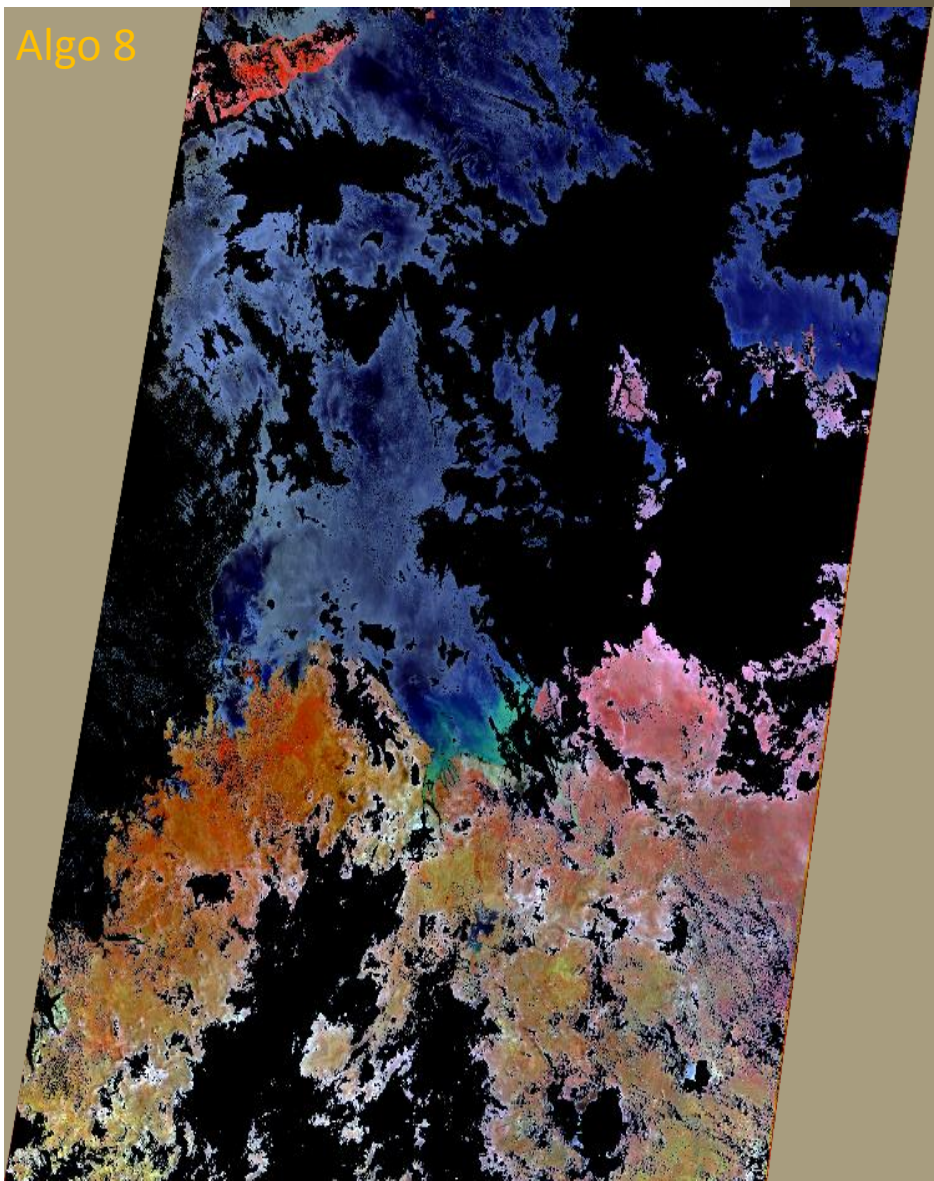
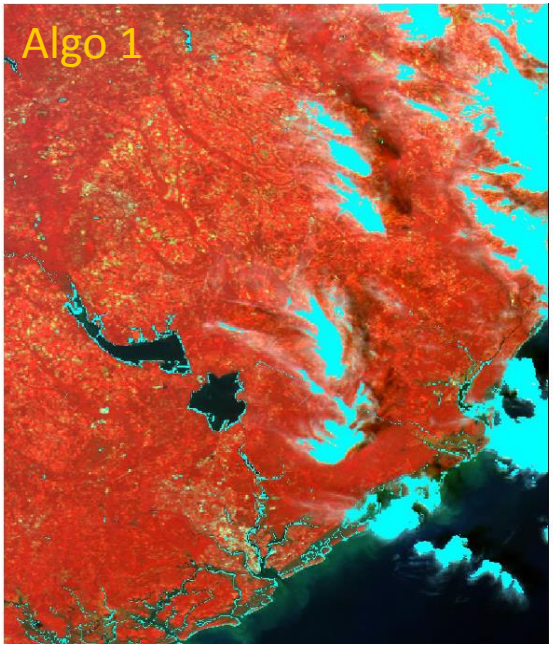
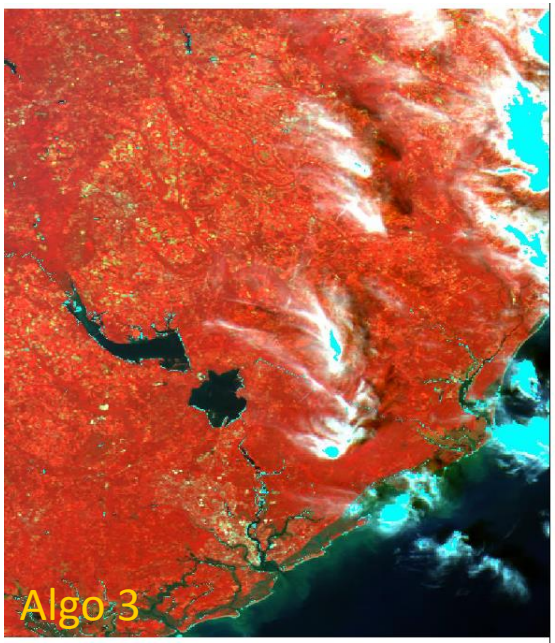




Assessment - Clouds over land and water, turbid coastal water





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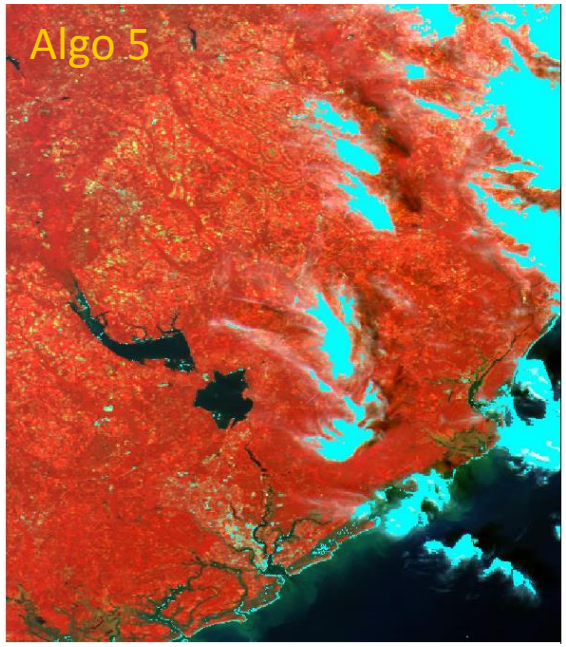
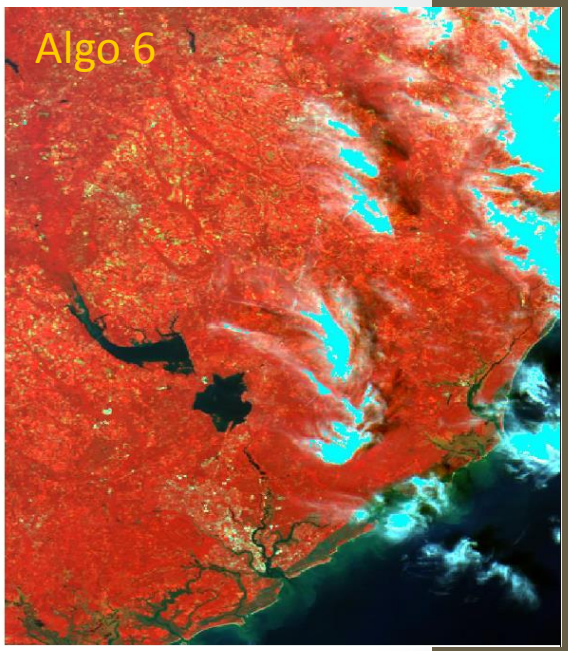
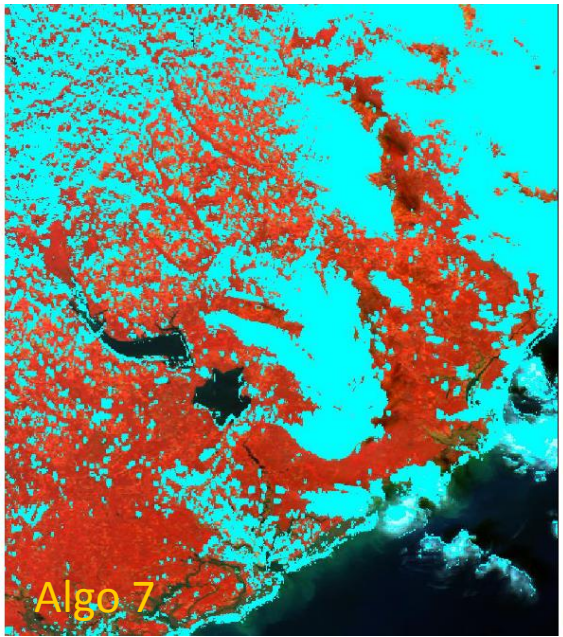
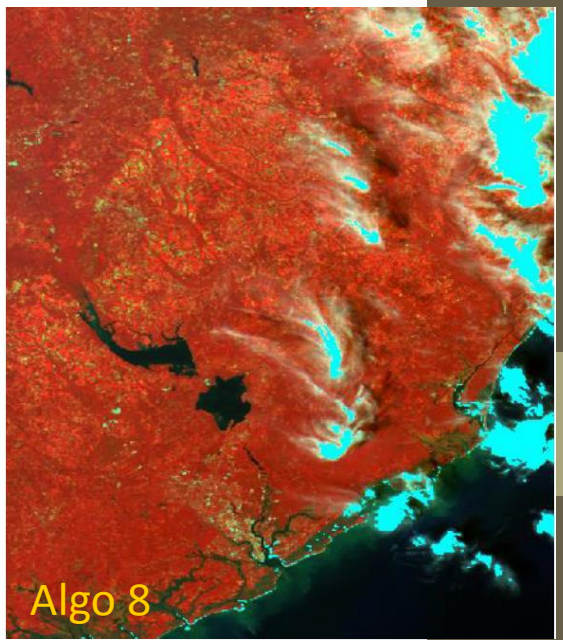








Matrices for the assessment

Producer's accuracy: How well a certain area can be classified (omission error)

User's accuracy: Reliability, probability a pixel class on the map represents the category on the ground (commission error)

Overall accuracy: Dividing the total number of correct pixels (diagonal) by the total number of pixels in the error matrix

Kappa(Hat): Measure of agreement between the classification map and the reference data

ProbaV Cloud Classification Version 1.0 - all surfaces (clo+semi)

In-Situ Database

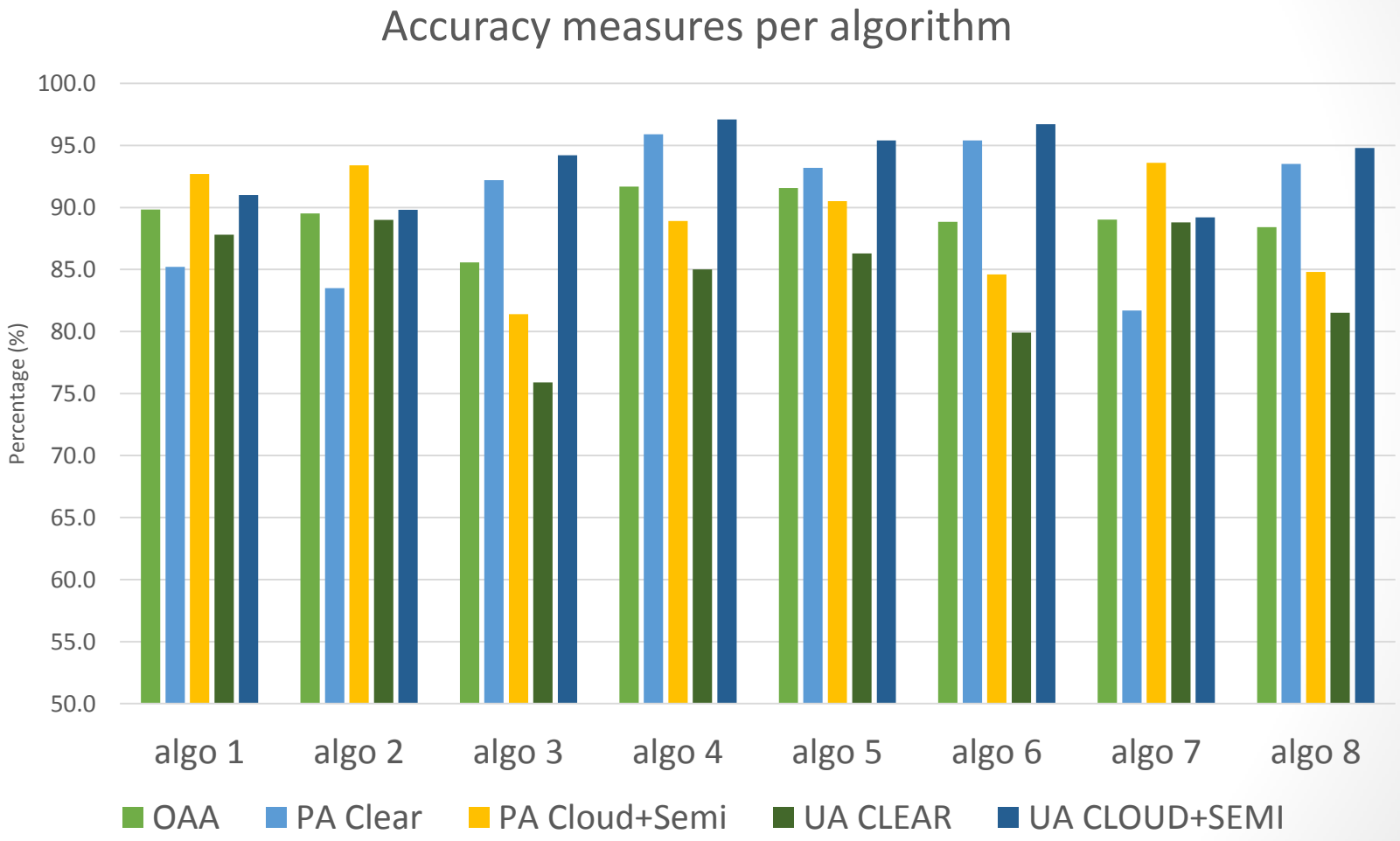
ProbaV	Class	Clear	Clo+semi	Sum	U A	E
	CLEAR	4986	1298	6284	79.3	20.7
	CLOUD	525	6345	6870	92.4	7.6
	Sum	5511	7643	13154		
	P A	90.5	83.0		OAA:	86.14
	E	9.5	17.0			

Scotts Pi: 0.719

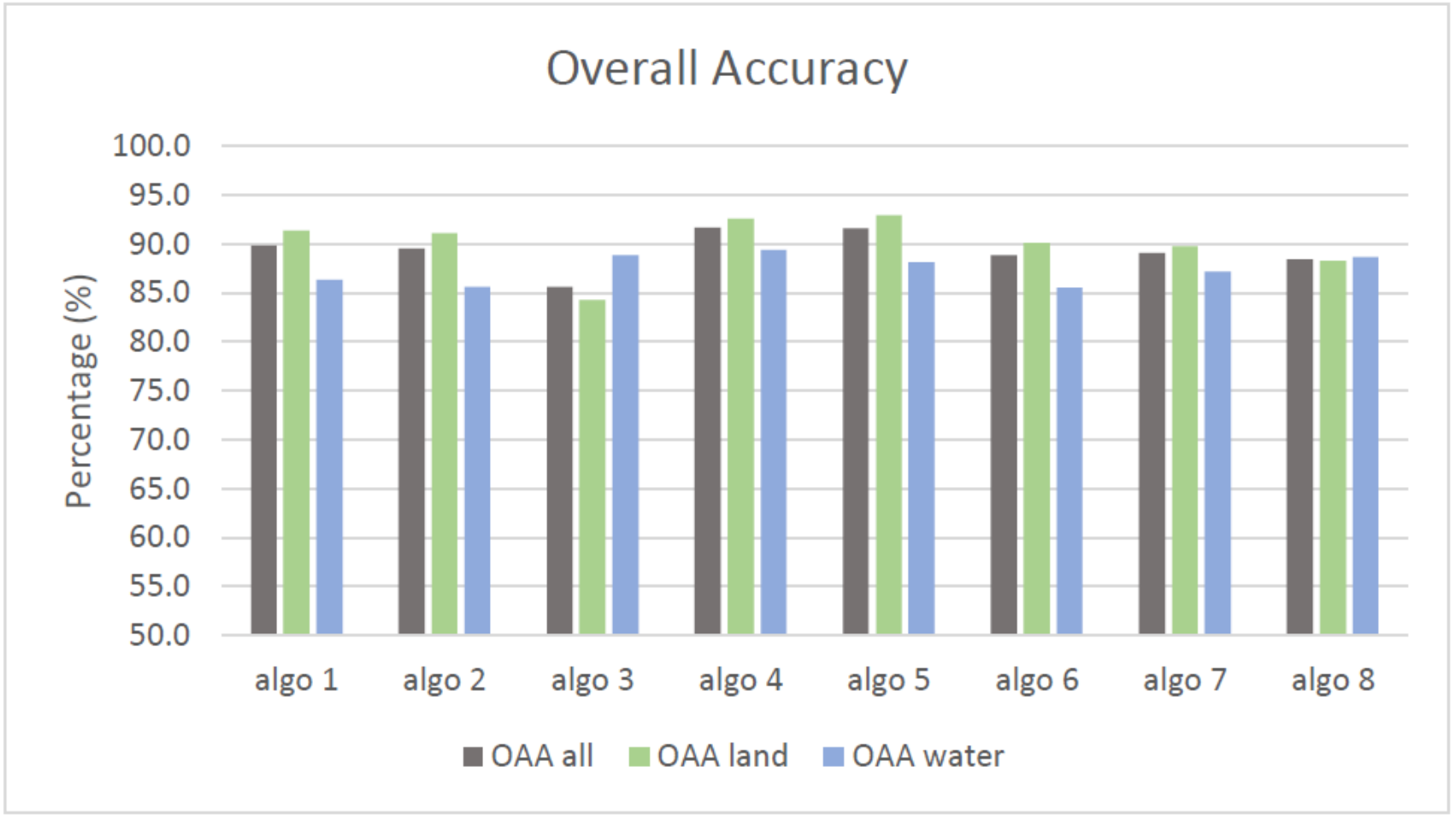
Krippendorfs alpha: 0.719

Cohens kappa: 0.72

Assessment 2 – Compilation of statistics

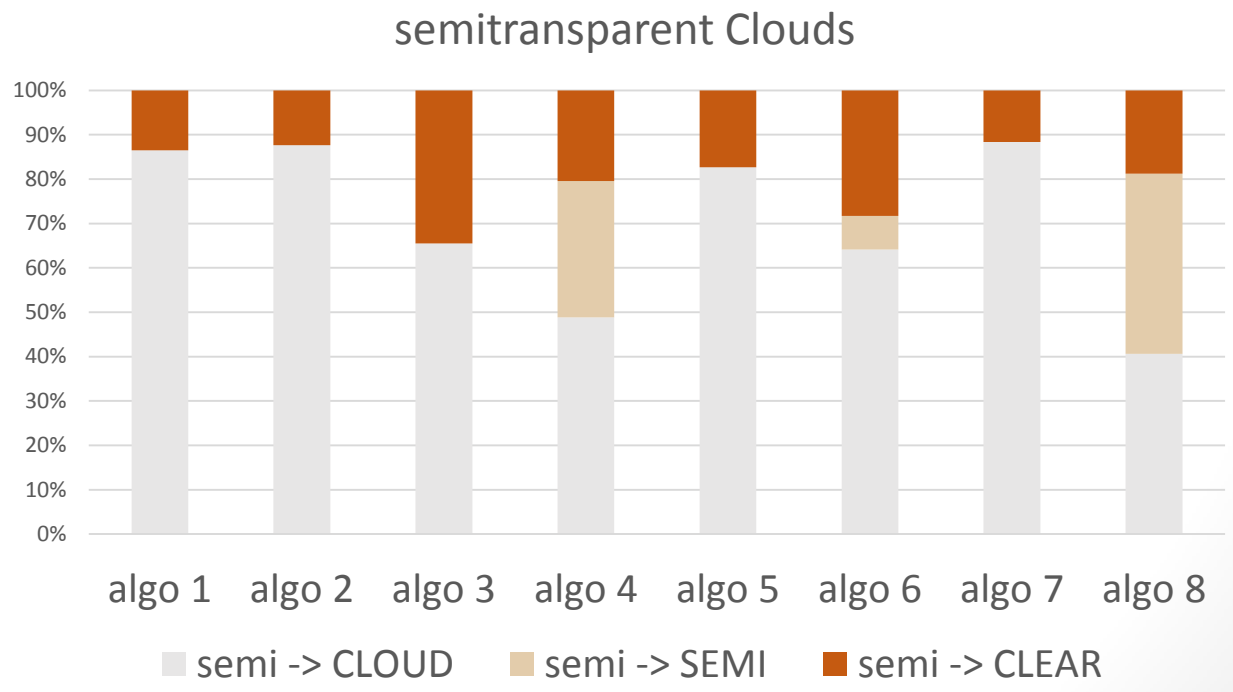


Assessment 2 – water-land separation

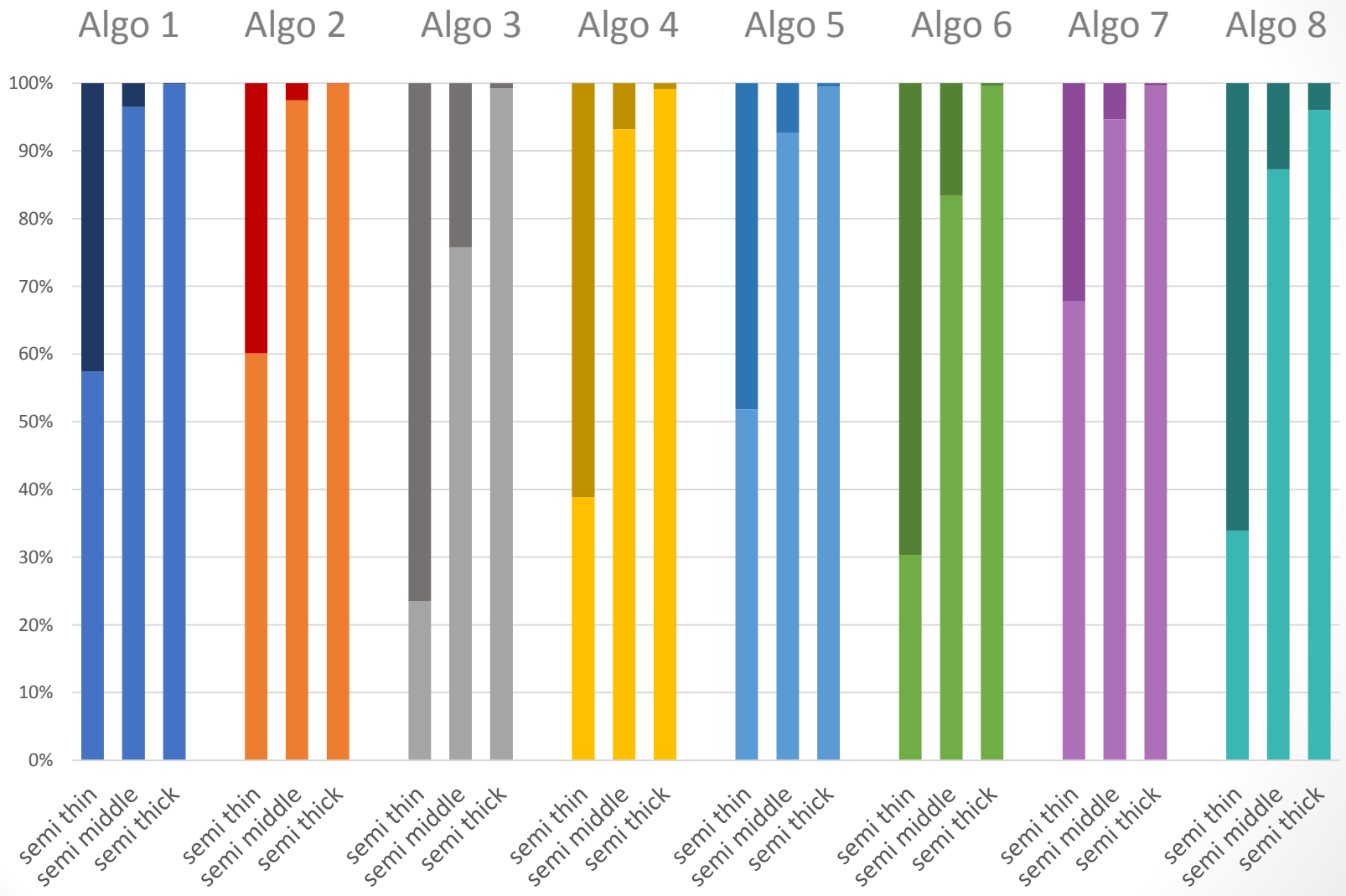


Assessment 3 - Semi-transparent Clouds

- How do the semi-transparent clouds behave.
  - Clear-sky conservative: (semi-transparent) clouds are flagged as CLOUD
  - Cloud conservative: (semi-transparent) clouds are flagged as CLEAR

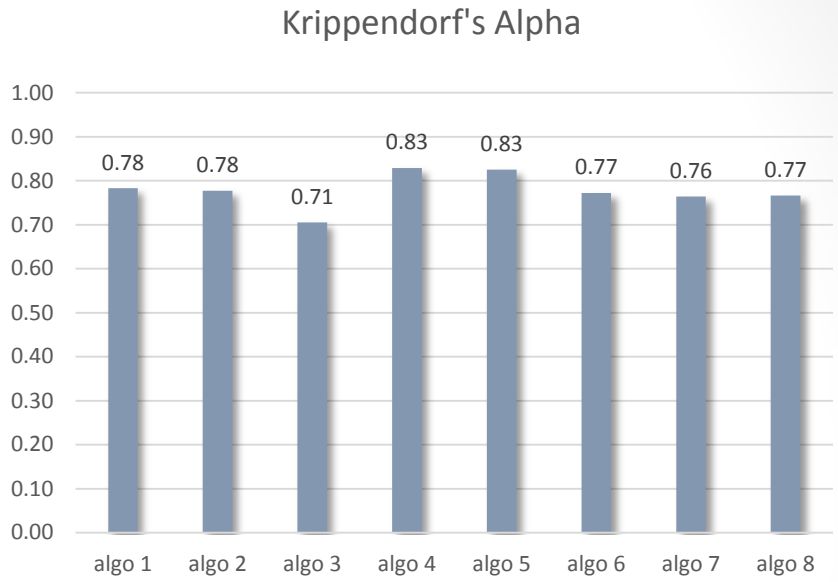


Assessment 3 - Semi-transparent Clouds



Overall Assessment

- Algo 4 and algo 5 show very high values in the statistics
  - Algo 5 is slightly more cloud conservative
  - Algo 4 is leaving out thick and bright clouds from the cloud mask.
- Algo 1 and algo 2 are very similar
  - algo 2 is more clear-sky conservative and flagging clear surfaces as cloud while having a good detection of semi-transparent clouds.



- Algo 3 and 6 are the ones detecting least clouds, but have very little commission errors, e.g. at coastlines or in inland waters or bright surfaces.

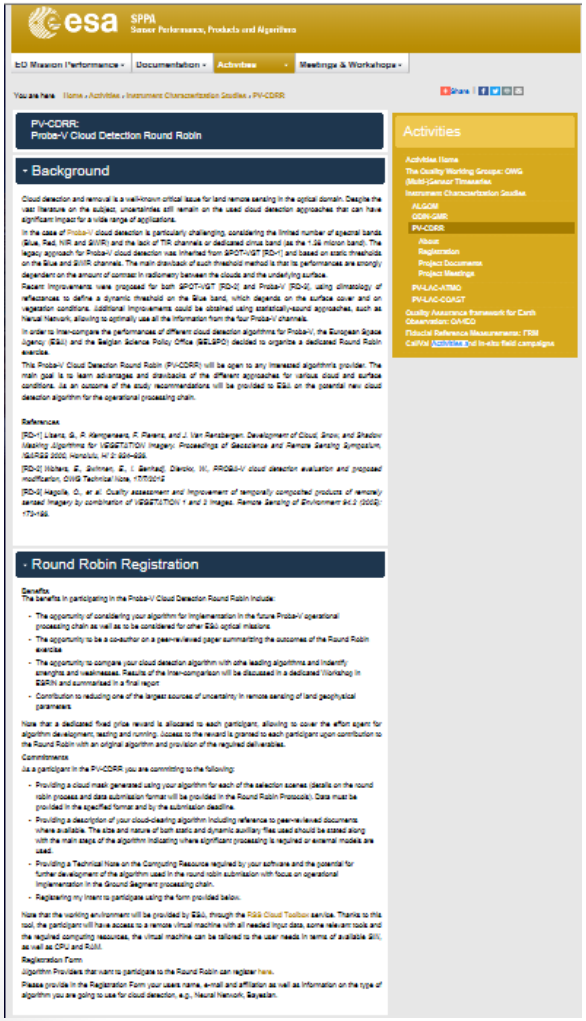
- Algo 7 is most clear-sky conservative and therefore detects small clouds, cloud borders and semi-transparent clouds but is flagging many clear pixels. Further, it shows artefacts at cloud borders over water.

- Algorithm 8 tends to be a cloud conservative algorithm over land, and a clear conservative algorithms over water.

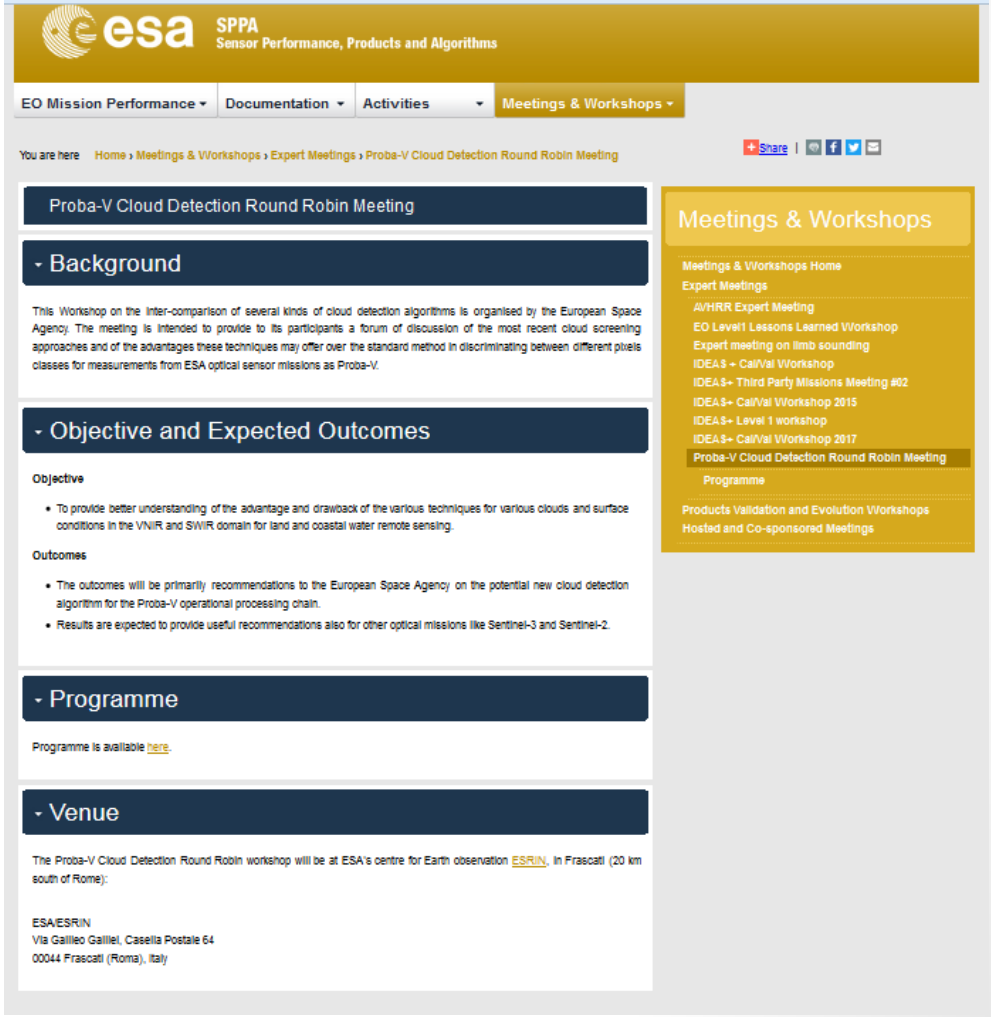
More Information

Esa Sppa Webpages

https://earth.esa.int/web/sppa/activities/instrument-characterization-studies/pv-cdrr



https://earth.esa.int/web/sppa/meetings-workshops/expert-meetings/proba-v-cloud-detection-round-robin-meeting



Conclusion

- Proba-V cloud detection and masking is extremely **challenging** due limited spectral bands, lack of TIR and cirrus band

- **State-of-the-art algorithms** have participated to this inter-comparison exercise

- Results are expected to **contribute to the advances** in the Proba-V operational processor and to provide useful **recommendations** for other optical missions S-3, S-2

Recommendations and lessons learnt

[LES-1]	*Appropriate definition of multi-textural features are essential for improving cloud discrimination over complex landscape and critical surface conditions, this can be an alternative to multitemporal approaches. Furthermore, for cloud/snow discrimination over mountainous areas, the use of the DEM can be an interesting option.*
[LES-2]	*The choice of a cloud mask, in particular with respect to clear-sky versus cloud conservative masks, remain challenging, being dependent on the requirements of the downstream applications.*
[LES-3]	*The usage of the MEP virtual environment for algorithm development requires non-negligible effort for code adaptation and SW environment porting, this is not ideal for short-time projects and when the size of input data is limited.*

[REC-1]	**Considering the effort spent in this validation dataset generation and the need of reuse it in the frame of future Proba-V QWG validation activities, it is recommended not to release the complete Round Robin Validation Dataset to the participants.**
[REC-2]	To consider similar Round Robin exercise with similar or different targets for fostering new ideas, following similar open call approach and a solid and well consolidated quality assessment protocol.
[REC-3]	In order to address the requirements of the various applications, leaving to the user the freedom to decide the level of cloud contamination that can be acceptable for its application, the best approach is to move toward a cloud probability mask, or at least to provide additional classes, e.g. thick clouds, semi-transparent clouds
[REC-4]	To expand the analysis and discussion of results with the goal of first submitting a contribution to MultiTemp2017 proceeding and possibly to a peer reviewed journal.

Final Recommendations

[REC-5]	*To evaluate the potential use of the best performing algorithms for implementation in the future processor baseline, and to investigate the issue of the current operational cloud mask in delineating cloud over water.*
[REC-6]	*All Algorithms are of good quality and Algo 4 and 5 are the best performers. In spite of that, considering additional criteria for the implementation of a new cloud detection algorithm, Algo5 is in pole position since:* • *No ancillary data are required* • *No multitemporal information is needed* • *Fast and parallel implementations for NN predictions*