Aerosol retrieval in presence of clouds

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How do clouds modify aerosol properties?

- The aerosol optical thickness (AOT) and particle size increase systematically approaching clouds.
- Effective particle size can either increase or decrease with the cloud fraction.
- Undetected clouds lead to to an overestimation of AOT from satellite measurements.

How do clouds modify aerosol properties?

- More than half of all aerosol measurements by passive satellite instruments come from near-cloud areas
- 3D radiative processes are significant and cause roughly 30% of the observed near-cloud AOD increase.
- However, aerosol retrieval algorithms are normally based on 1D models, and are therefore not capable of representing 3D effects.

Cloud mask for aerosol retrieval applications

- To avoid cloud-related artifacts in aerosol retrieval, the cloud mask is normally chosen to be conservative.

PROS

Aerosol retrieval only over cloud-free pixels, far from clouds

Reduced probability of undetected clouds

CONS

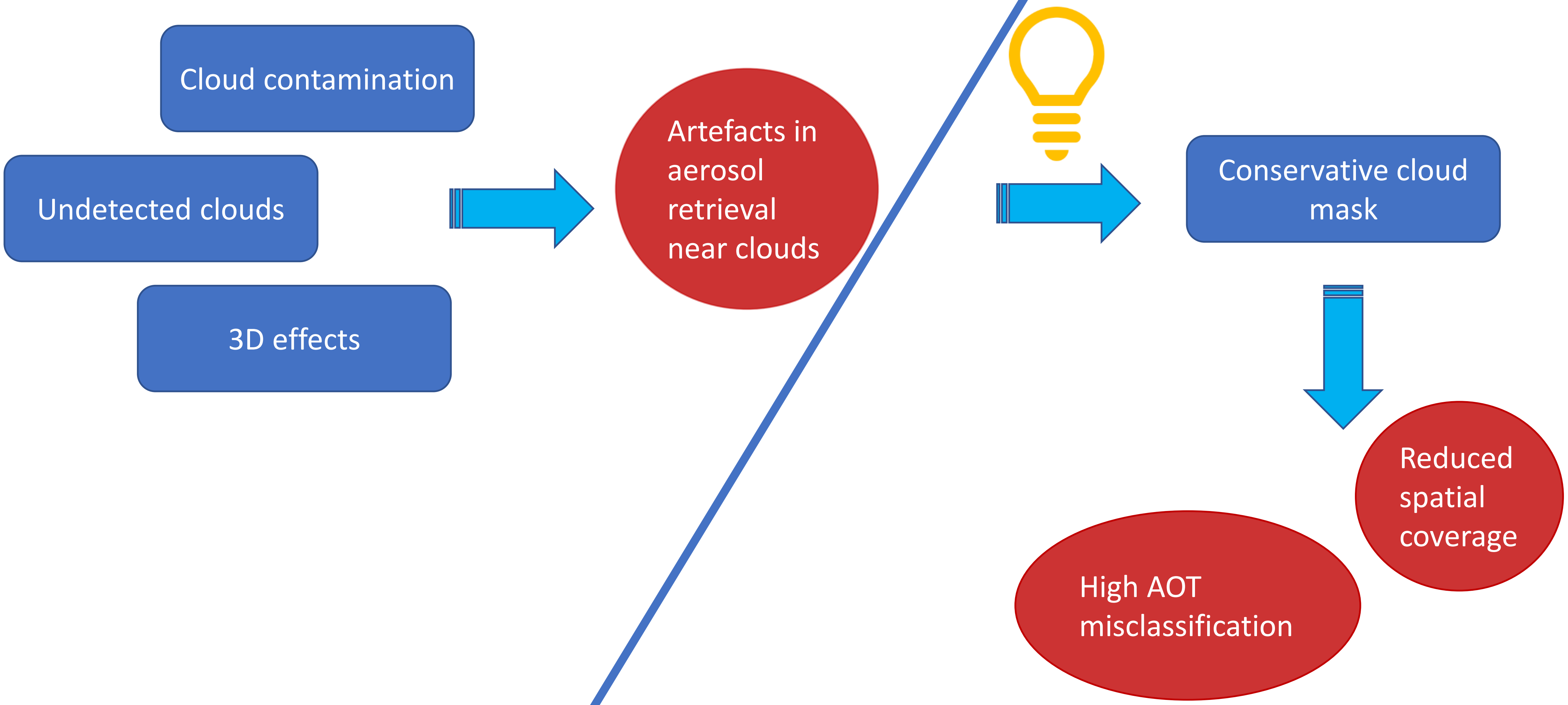
reduced spatial coverage

Higer probability of high aerosol events being misclassified as clouds (commision errors)

Cloud mask impact on AOT products

- The Aerosol-CCI project showed how the choice of the cloud mask strongly affect the outcome of aerosol retrieval algorithms (Holzer-Popp et al., 2013).
- Sogachava et al. (2020) indentified in the different cloud masking approach a source of discrepancy between different aerosol products.

In summary


Cloud contamination
Undetected clouds
3D effects
Artefacts in aerosol retrieval near clouds
Conservative cloud mask
Reduced spatial coverage
High AOT misclassification

How to solve cloud-related problems in aerosol retrieval? [1]

Cloud mask improvement

- A large effort is made in improving cloud masking algorithms to be conservative enough to discard partially cloudy pixels while minimising the misclassification of high AOTs.

Post processing techniques

- Lipponen et al. exploit machine learning techniques to improve the accuracy of the satellite aerosol data products and reduce the associated uncertainties from MODIS.
- Similarly, Sogacheva et al. developed a Cloud Post Processing scheme to remove cloud contaminated areas.

How to solve cloud-related problems in aerosol retrieval? [2]

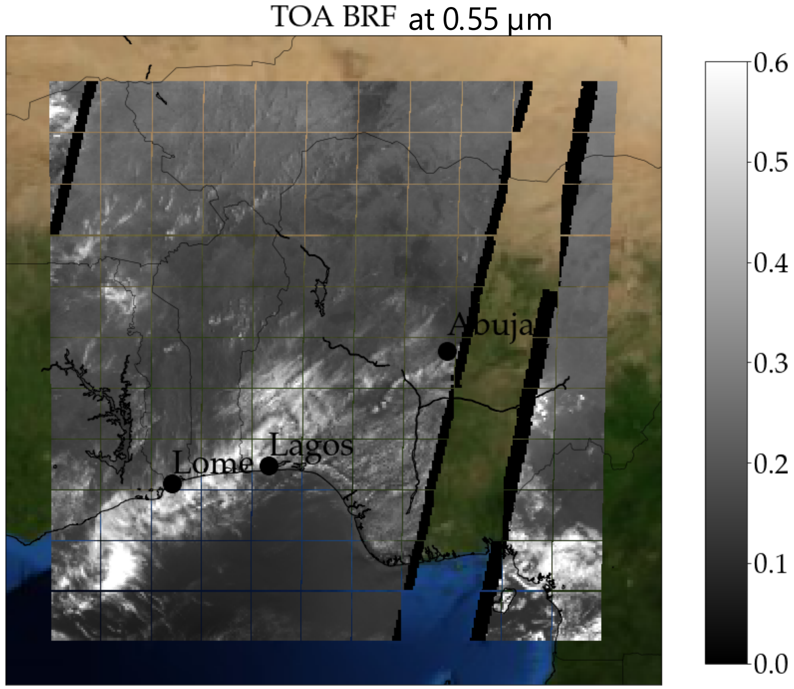
Improved input data

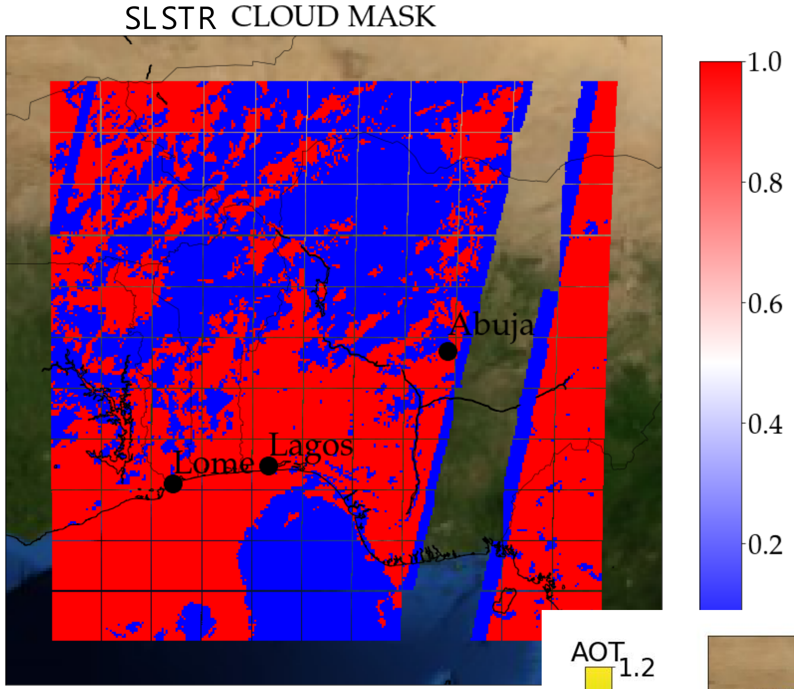
- Many studies have shown the possibility of using polarization to detect, for instance, Aerosol Above Clouds (AAC) (Waquet et al., 2013).
- The combined used of active and passive instruments has been exploited to better constraint aerosol retrieval (Thorsen et al., 2017)
- Higher resolution data could improve the coverage of aerosol in near-cloud areas. However the 3D effects will then be the primary cause of high AOD near clouds (Spencer et al., 2019)

How to solve cloud-related problems in aerosol retrieval? [3]

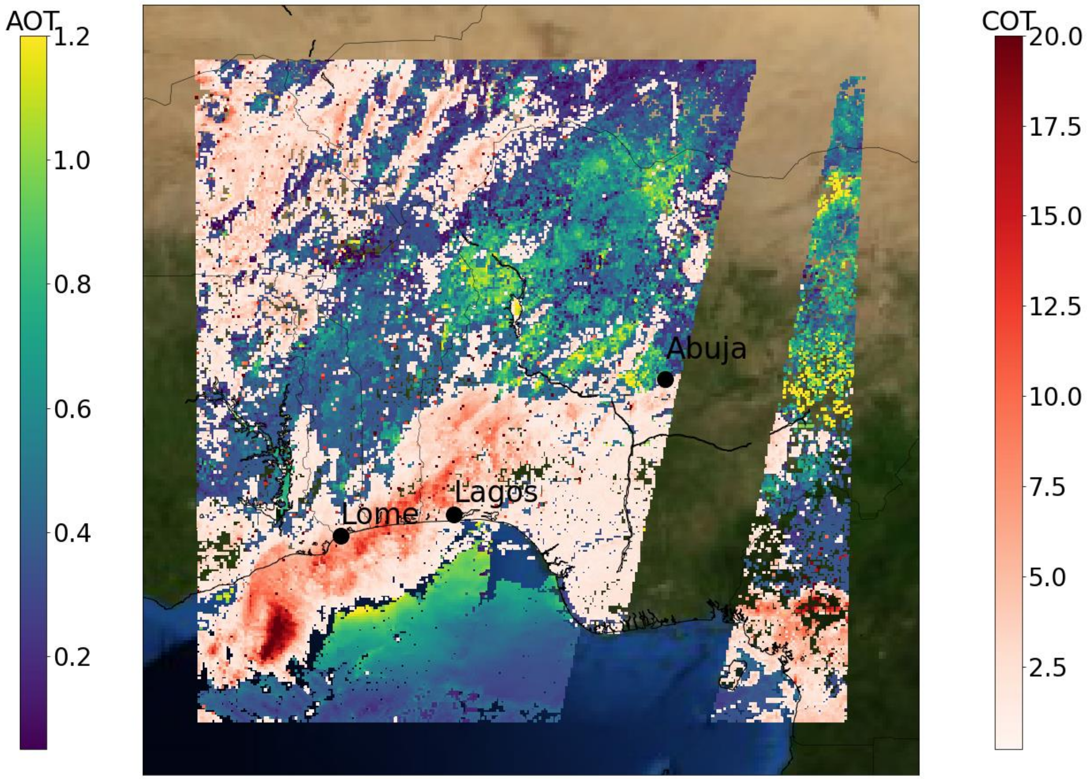
Radiative transfer based approach

- At Rayference, we developed an algorithm (CISAR) for the joint retrieval of surface reflectance, aerosol and cloud single scattering properties.
- The algorithm is based on the online inversion of a 1D model.
- After a short training period, CISAR no longer requires a pre-processing cloud screening and retrieves both cloud and aerosol optical thickness within the same pixels.





CISAR



Retrieval over Nigeria from Sentinel-3/SLSTR during 21st April 2019

Conclusions

- Aerosol retrieval in near clouds areas represent more than 50% of all aerosol measurements. However, cloud strongly affect aerosol properties.
- The cloud mask is a key parameters for aerosol retrieval algorithm.
- Several methods are developed to overcome cloud-related issues in aerosol retrieval applications. Each with its advantages and disadvantages.
- CISAR is a promising tool to address cloud contamination, misclassification of high AOTs and decreased spatial coverage in near cloud areas.

Way forward

- The accuracy of 1D models can be improved by adding additional atmospheric layers, at the expenses of longer computational time.
- Ideally, aerosol retrieval algorithm should be based on 3D models, to correctly account for 3D cloud-aerosol effects.
- Aerosol retrieval near cloud at higher spatial resolutions will be feasible if 3D cloud related effects can be correctly taken into account.

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