Status of Aeolus L2A product, instrument calibration and mid term plans

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Summary

1) Overview of the L2A product

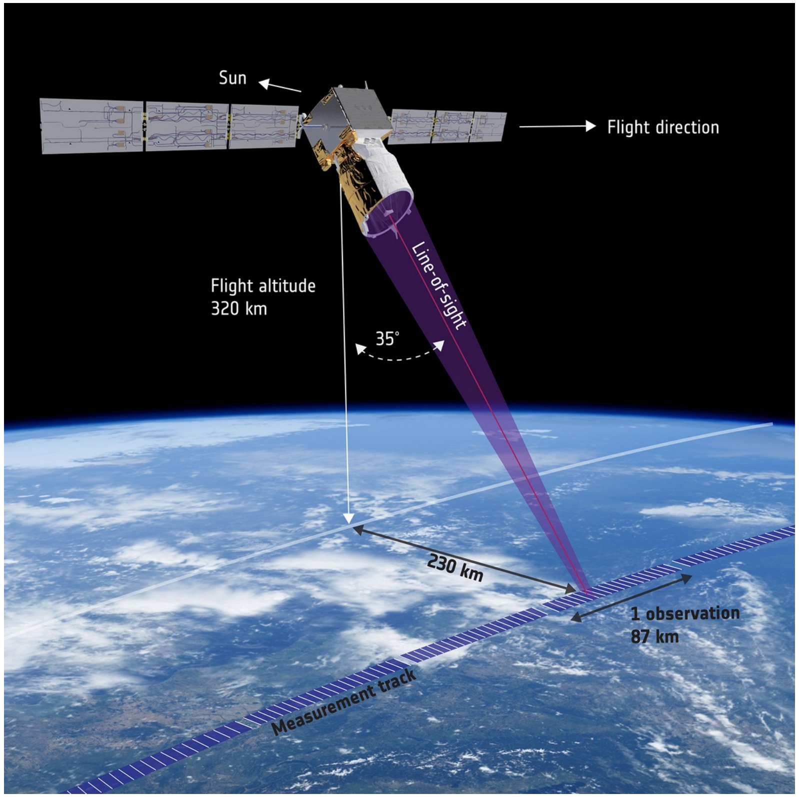
2) Standard Correct Algorithm and Calibration

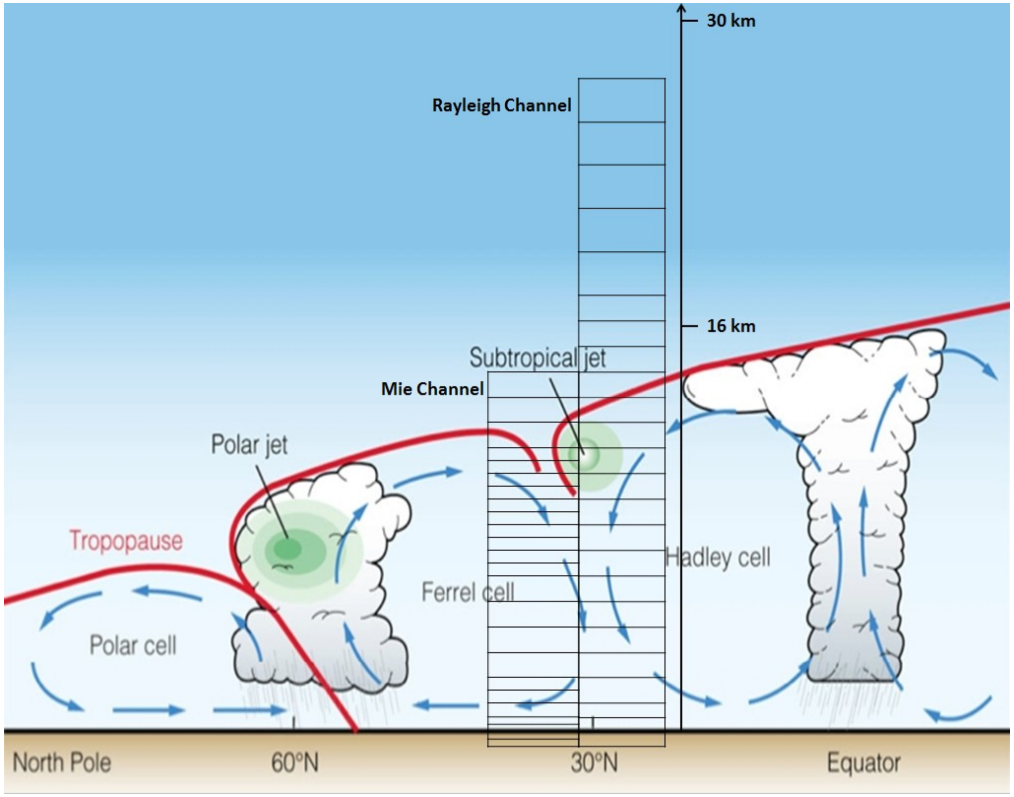
3) Improvements of the algorithm: Maximum Likely-hood Estimation (MLE)

4) Example of L2A output with test cases

5) Summary and future evolution

Measurement Geometry





1 Observation = 1 Basic Repeat Cycle (BRC) = 30 measurements

1) Overview of the L2A products

<table>
<tr><th>V3 .12
(Currently available for download)</th><th>V3 .13
(Available in ...)</th><th>Ongoing developments</th><th></th></tr>
<tr><td colspan="3">Standard Correct Algorithm (SCA) : L2A Core Processor</td><td rowspan="4">BRC scale</td></tr>
<tr><td colspan="3">Mie Correct Algorithm (MCA) : Use the Mie channel only</td></tr>
<tr><td colspan="2">Iterative correct algorithm (ICA) : Subdivide height bins vertically for bins partially filled with particles</td><td></td></tr>
<tr><td colspan="2"></td><td>Maximum Likelyhood Estimation (MLE)</td></tr>
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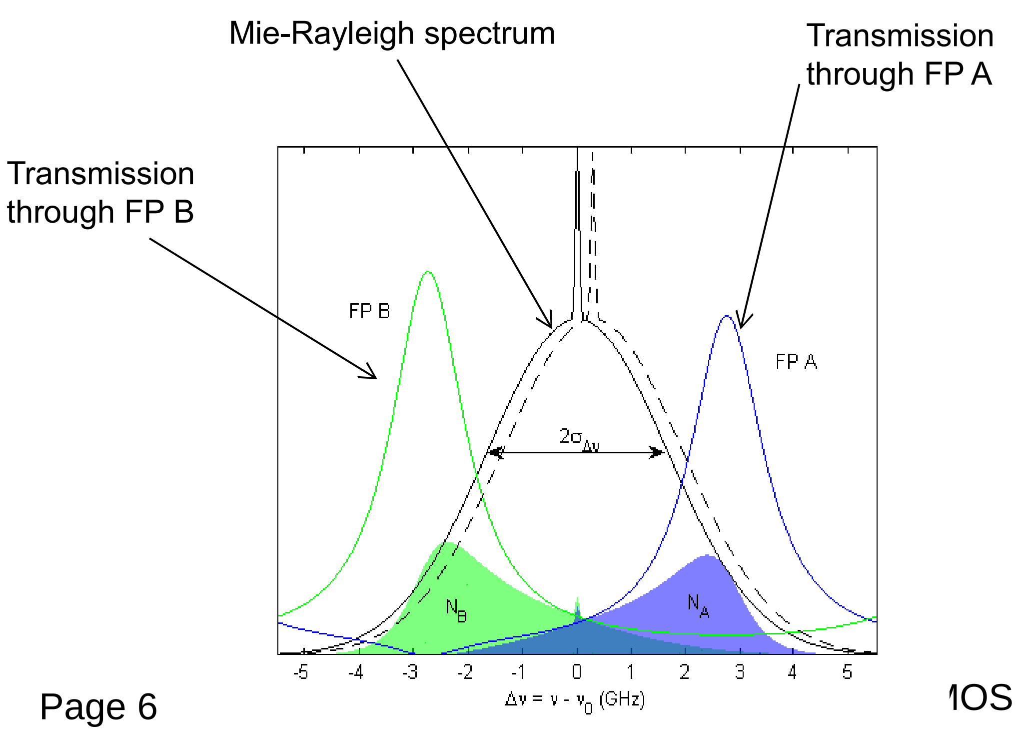
1) Overview of the L2A products

V3 .12 (Currently available for download)	**V3 .13** (Available in ...)	Ongoing developments	
Standard Correct Algorithm (**SCA**) : L2A Core Processor			BRC scale
Mie Correct Algorithm (**MCA**) : Use the Mie channel only			
Iterative correct algorithm (**ICA**) : Subdivide height bins vertically for bins partially filled with particles			
		Maximum Likelyhood Estimation (**MLE**)	
Group Algorithm		Group Algorithm ⇕	Measure- -ment scale
		MLE at sub BRC scale	

2) Standard Correct Algorithm and Calibration

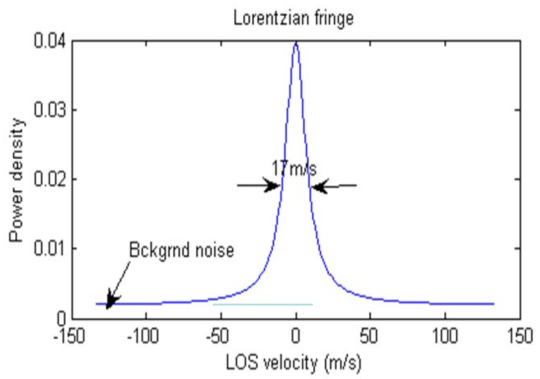
Rayleigh channel (molecules) :

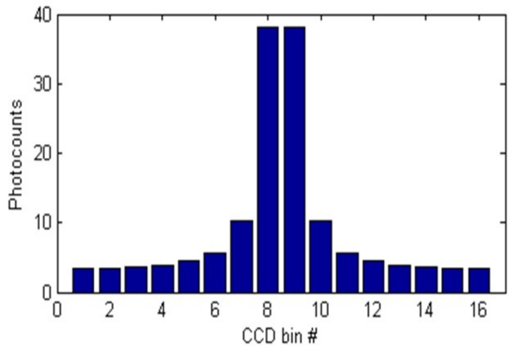
- Collected light go through two Fabry-Pérot interferometers : FPA and FPB.
- The ratio between the number of collected photon : (NA-NB)/(NA+NB) is converted in doppler,shift based on calibration curves.



Mie channel (particules) :

- Collected light go through a Fizeau interferometer.
- The Doppler shift is estimated from the fringe position.

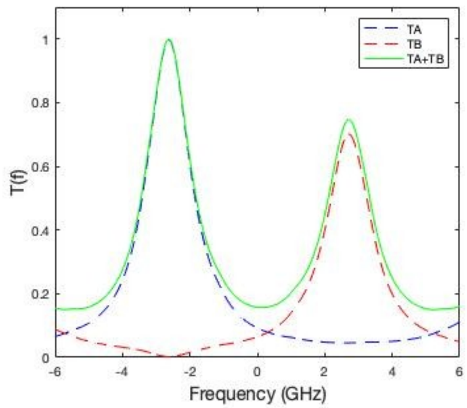




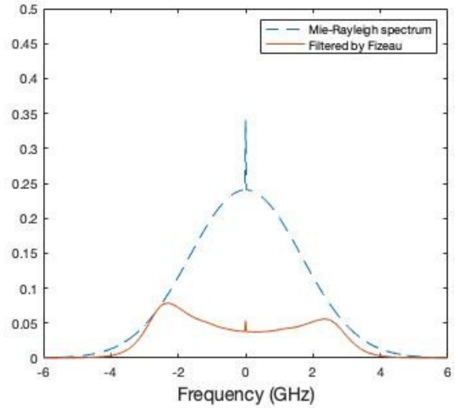
2) Standard Correct Algorithm and Calibration

The signals S_{Ray} and S_{Mie} accumulated in each channel, both contain molecular contributions and particular contributions :

Rayleigh channel

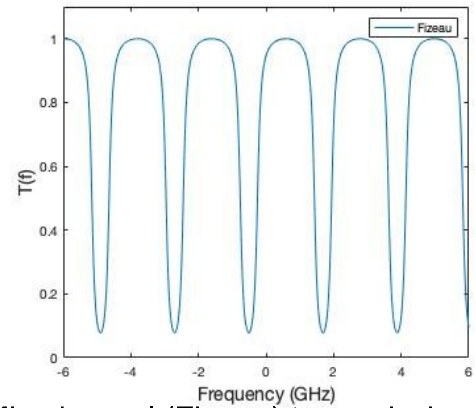


Rayleigh channel (FPA and FPB) transmission curve

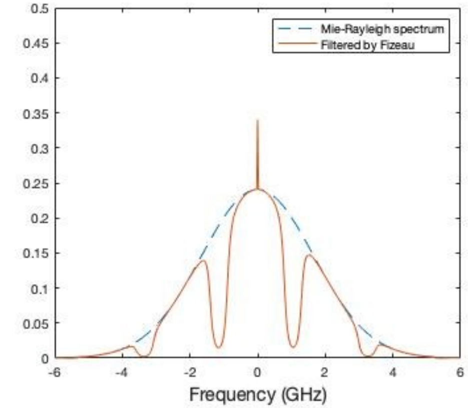


Mie-Rayleigh spectrum through the Rayleigh channel

Mie channel



Mie channel (Fizeau) transmission curve



Mie-Rayleigh spectrum through the Mie channel

2) Standard Correct Algorithm and Calibration

- Quality of calibration mode data and models greatly impact the crosstalk correction and therefore the quality of L2A products
- K_{Ray} and K_{Mie} characterize the radiometric efficiency of the two receivers. **They were considered as constants** that can be determined from signal levels recorded in calibration mode

Accumulated lidar signals for Rayleigh and Mie channels :

$$S_{Ray}=K_{Ray}\frac{E_0}{R^2}[C_1\beta_{mol}+C_2\beta_{part}]T^2_{mol}T^2_{part}$$

$$S_{Mie}=K_{Mie}\frac{E_0}{R^2}[C_4\beta_{mol}+C_3\beta_{part}]T^2_{mol}T^2_{part}$$

Calibration coefficients taken from AUX_CAL and AUX_MET :

C1(P,T,v) = Rayleigh in Fabry Pérot
C2(v) = Mie signal in Faby Pérot
C3(v) = Mie signal in Fizeau
C4(P,T,v) = Rayleigh signal in Fizeau
K_{Ray}, K_{Mie}

Crosstalk-corrected signals :

$$\beta^{Att}_{mol}=\beta_{mol}T^2_{mol}T^2_{part}$$

$$\beta^{Att}_{part}=\beta_{part}T^2_{mol}T^2_{part}$$

$$\beta_{part}=(\beta^{att}_{part}\beta_{mol})/\beta^{att}_{mol}$$

$$\alpha_{part}=d(\beta^{att}_{mol}\beta_{mol}T^2_{mol})/dR$$

2) Standard Correct Algorithm and Calibration

- **K_{Ray} and K_{Mie} are fitted per observation by using telescope temperatures** : Thermal constraints (i.e. outer-inner temperatures gradient of the telescope) vary along the orbit and affect the L2A radiometric performance

➡ A corrective scheme based on ALADIN telescope temperatures (i.e. multiple linear regression) is applied : **we fit the K_{Ray} and K_{Mie} per observation** by using mirror temps.

$$Predicted\ K_{Ray} = \beta_0 + \beta_1 * X_1 + \ldots + \beta_p * X_p + \epsilon$$

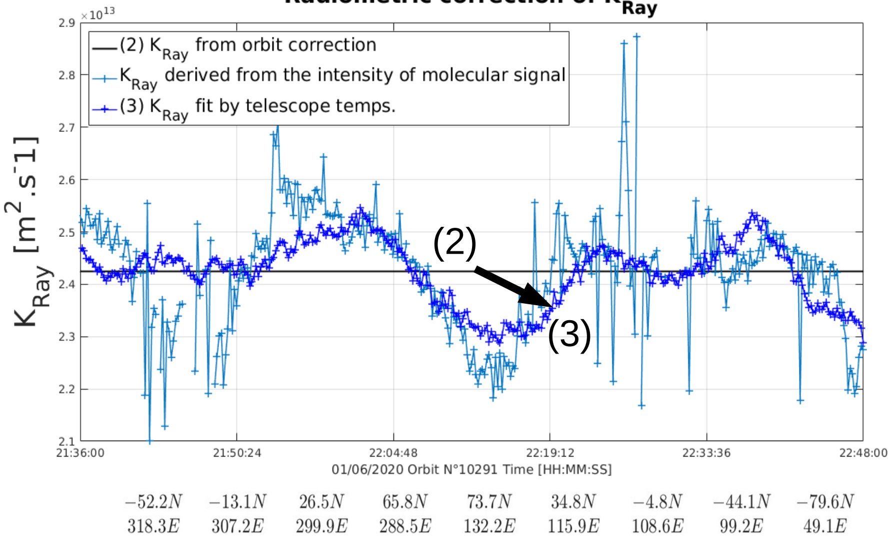
$$Predicted\ K_{Mie} = \beta_0 + \beta_1 * X_1 + \ldots + \beta_p * X_p + \epsilon$$

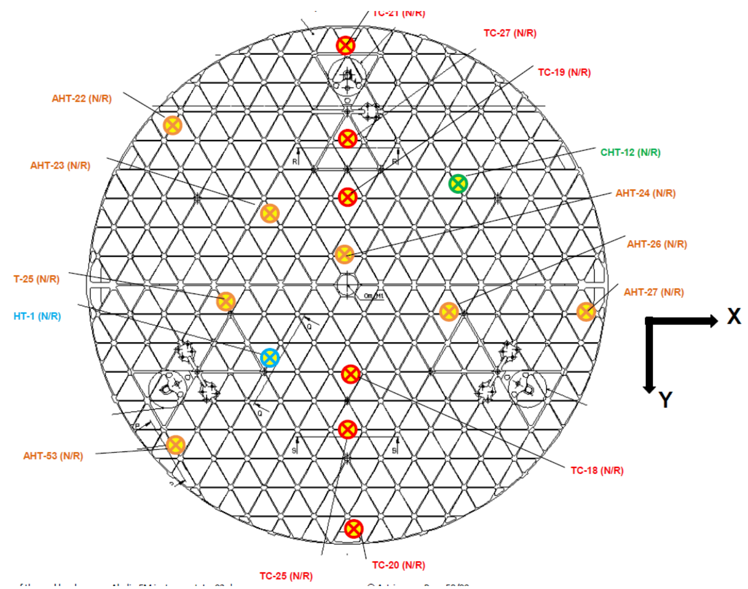
$$\beta_0 \ldots \beta_p = mirror\ temperatures$$

$$X_1 \ldots X_p = regression\ coefficients$$

=> 12 temperatures timelines are taken from sensors distributed all over the mirror telescope :

Radiometric correction of K_{Ray}





2) Standard Correct Algorithm and Calibration

- Spatial heterogeneity and accumulation length make the comparison with ground observations good.
- In some condition with good spatial homogeneity, comparisons are good :

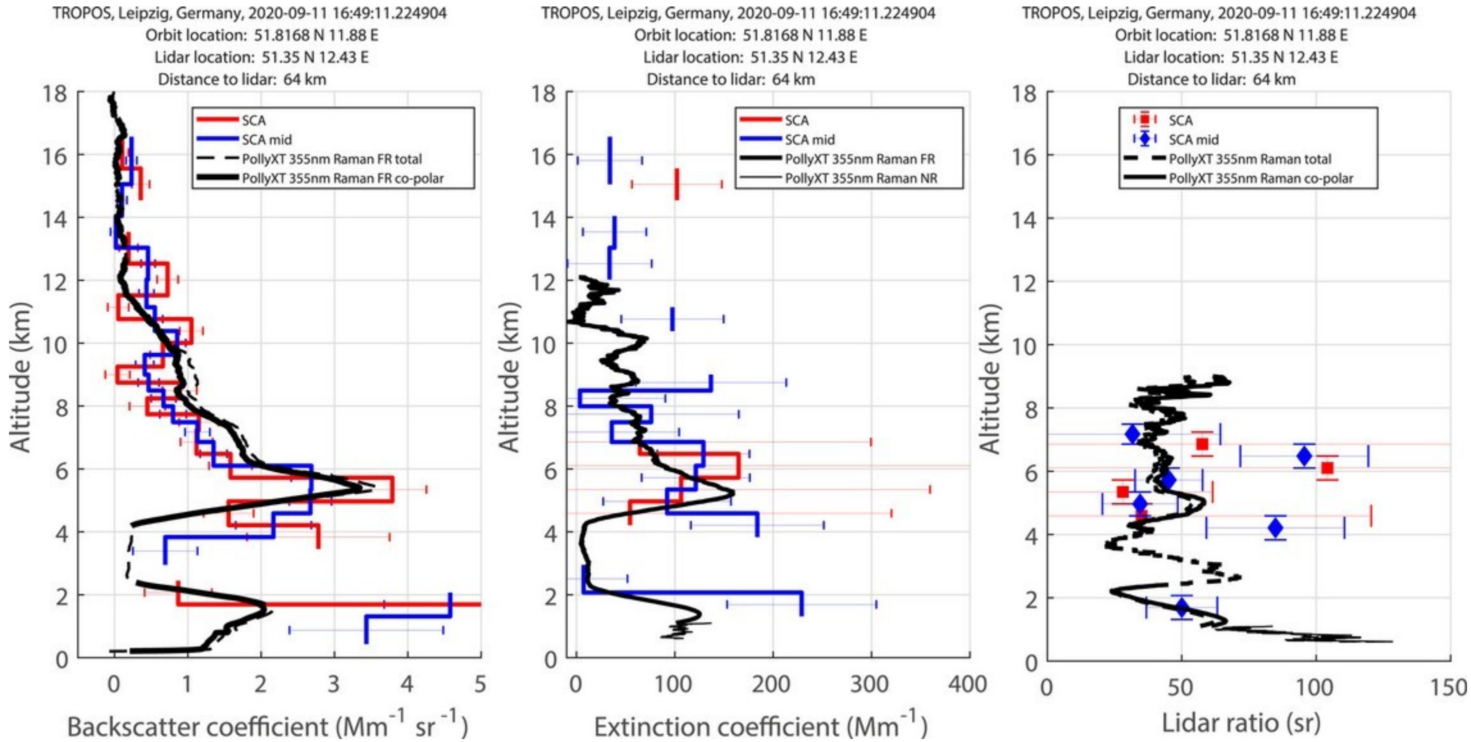


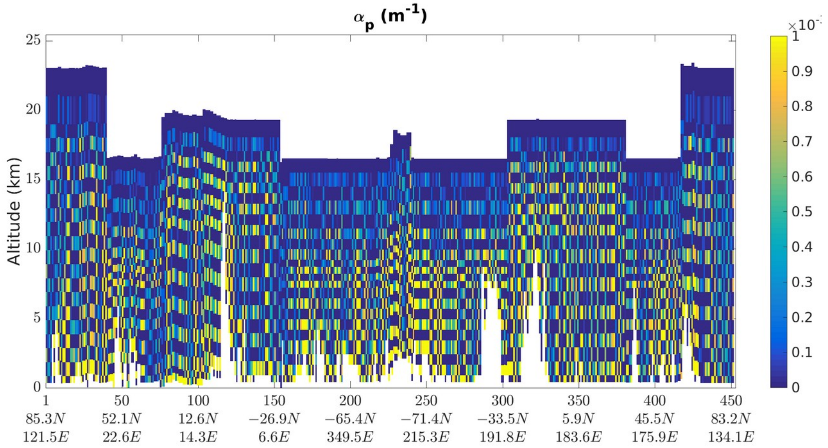
Figure 5. Comparison of the optical profiles provided by Aeolus (green and red) and the ground-based EARLINET lidar PollyXT (black lines). The particle backscatter coefficient (left), the particle extinction coefficient (center), and the corresponding lidar (extinction-to-backscatter) ratio is shown. The ground-based backscatter observations (dashed line) are converted to Aeolus-like, i.e. co-polar, profiles (solid line) for comparability.

Baars et al., (2021)

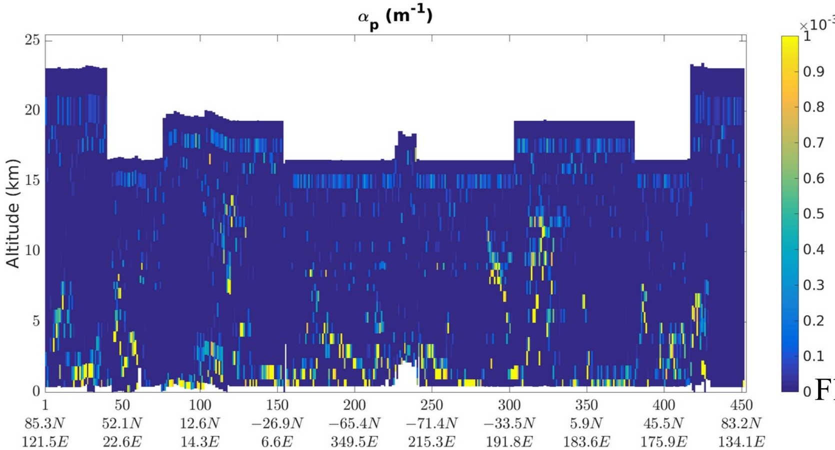
Baars et al., 2021

2) Standard Correct Algorithm and Calibration

- The estimation of the extinction uses a recursive method were we compare the observed molecular signal to the molecular signal simulated from the atmospheric conditions (p and T).
  - The signal on one bin is attenuated by the overlying bins.
  - It is assumed that the particulate extinction is zero in the first bin (i.e. topmost bin).
  - Molecular signals are normalized by the signal of the first bin to ignore the potential attenuation between the topmost bin and the satellite.
- It comes that **the algorithm is very sensitive to the noise of the first bin** generally located between 20-25 km where the molecular signal is low i.e. the SNR is low.
- As a consequence, **the error propagate and is amplified toward the bottom** and the retrieved extinction have an oscillating behavior.
- **Users are advised to use the mid-bin product**. The mid-bin grid average two consecutive bins and therefore more signal is accumulated.



Negative extinction not reset to 0



Negative extinction reset to 0

Flament et al. 2021

3) Improvement of the algorithms : Maximum-Likelihood Estimation (MLE)

- Lidar signals were weaker than expected. The SCA suffer from this noise.
- An optimization method based on physically constrained variables is being implemente :

Soit le modèle *y* = *F(x)* tel que :

$$\boldsymbol{y} = \begin{pmatrix} s_{\text{ray},0} \\ \vdots \\ s_{\text{ray},n} \\ s_{\text{mie},0} \\ \vdots \\ s_{\text{mie},n} \end{pmatrix} \quad \text{and} \quad \boldsymbol{x} = \begin{pmatrix} L_{p,0} \\ \vdots \\ L_{p,n} \\ \gamma_{||,p,0} \\ \vdots \\ \gamma_{||,p,n} \\ L_{p,sat} \end{pmatrix}, \quad n \leq 24.$$

L = épaisseur optique
γ = Lidar ratio

A state of the atmosphere *(x)* is determined by minimizing the cost function :

$$\min_{\substack{\boldsymbol{x};\\ 2\text{ sr}<\gamma_{||,p}<200\text{ sr};\ 0<L_p}} [\boldsymbol{y} - \boldsymbol{F}(\boldsymbol{x})]^{\mathsf{T}}\, \mathbf{S}_{\mathbf{y}}\, [\boldsymbol{y} - \boldsymbol{F}(\boldsymbol{x})]$$

Ehlers et al. 2021

Optical depth and Lidar Ratio are constrained to respect physical limits. **($L_p > 0$ and $2\ \text{sr} < \gamma_p < 200\ \text{sr}$)**

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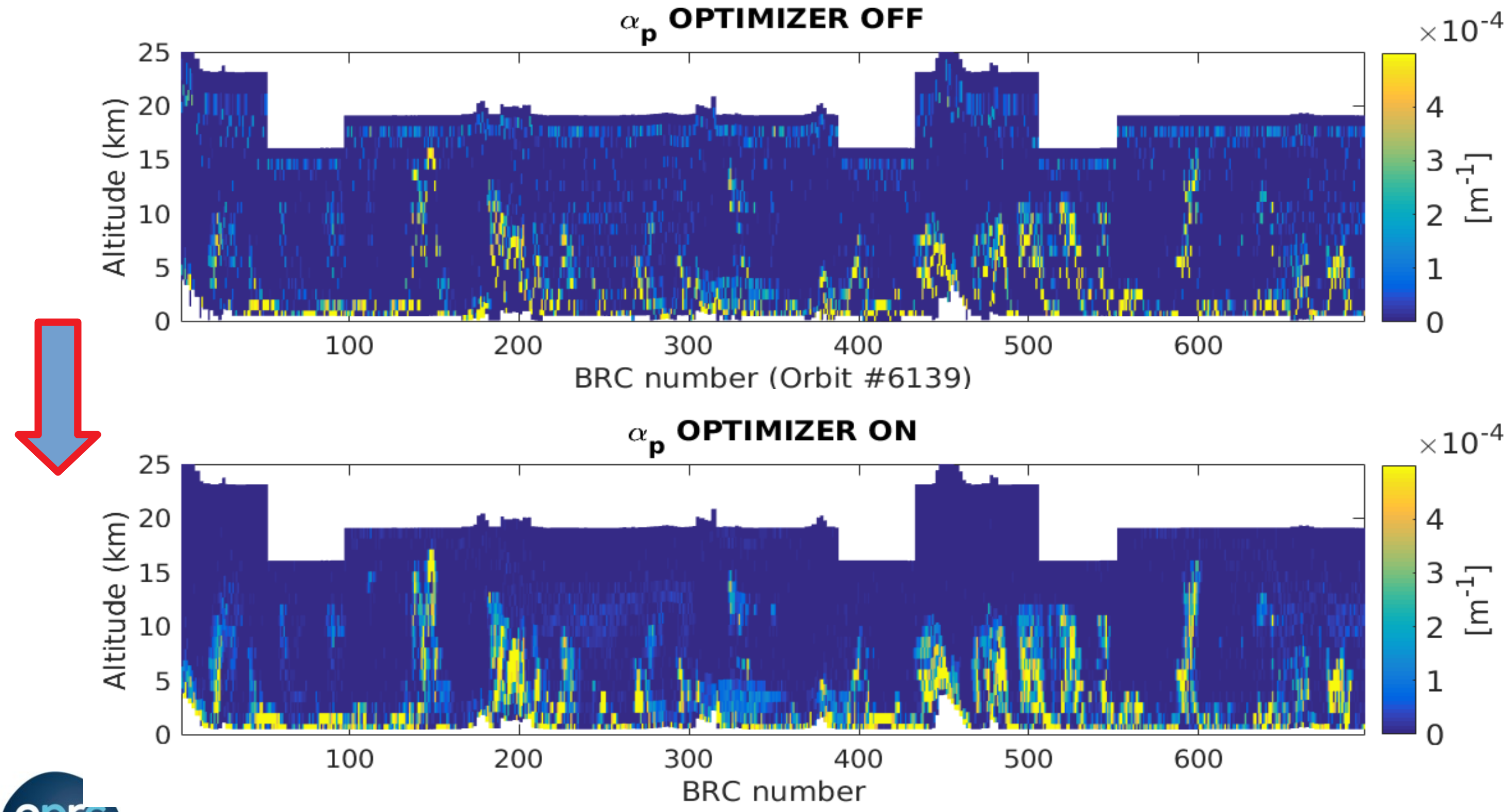
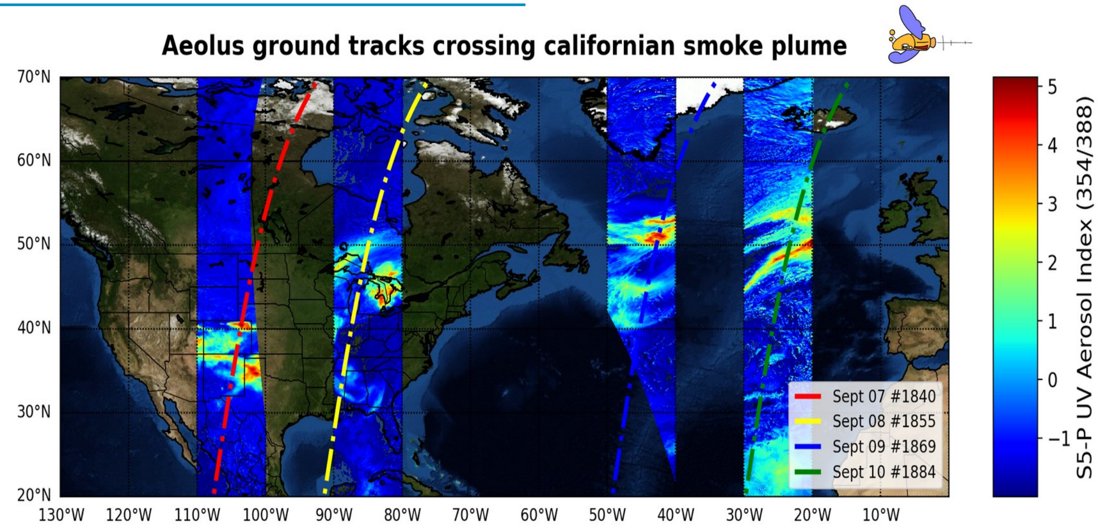
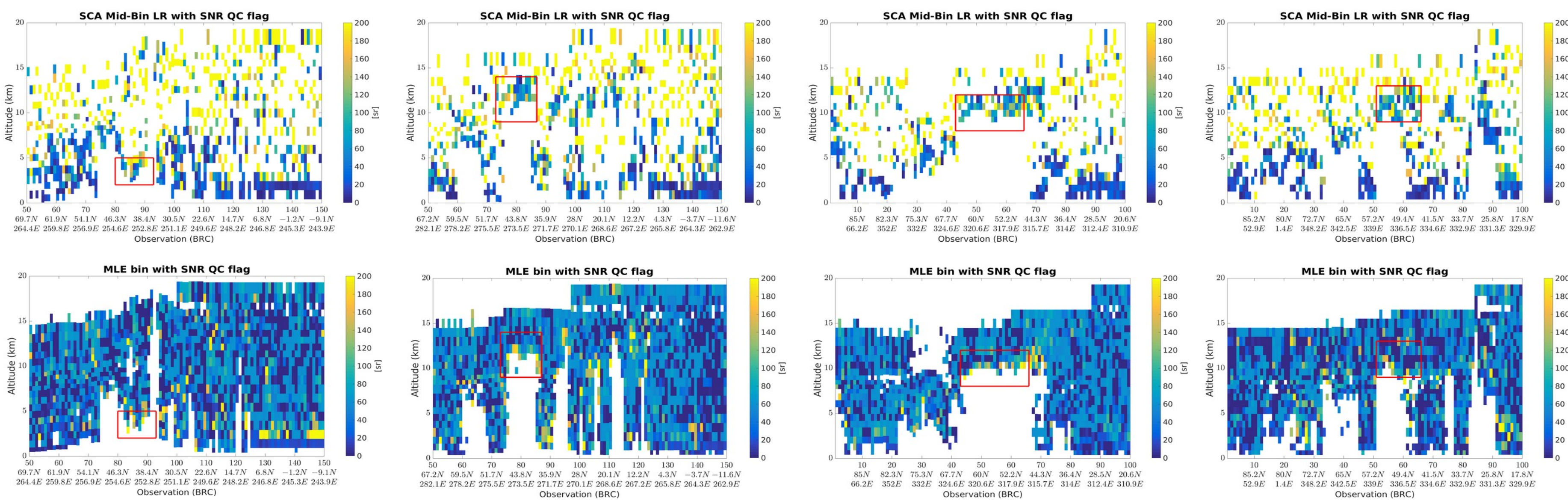


4) Example of L2A output : tracking the californian wildfire plume using SCA and MLE retrievals

- The plume signature can be seen in both SCA and MLE extinction to backscatter ratio
- **MLE is consistent** as is produces coherent LR values for such smoke (~60-80 sr)
- **Highest lidar ratio is observed far from the emission source** :

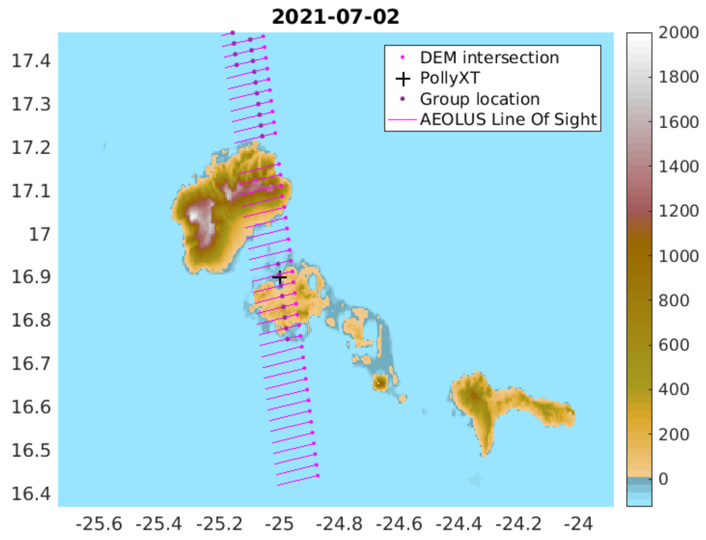
  => as **the core plume is stabilizing through the tropopause** it get contaminated by ice crystal or water droplets resulting in higher portion of cross polarized backscatter missed by Aeolus => the lidar ratio then tends to increase

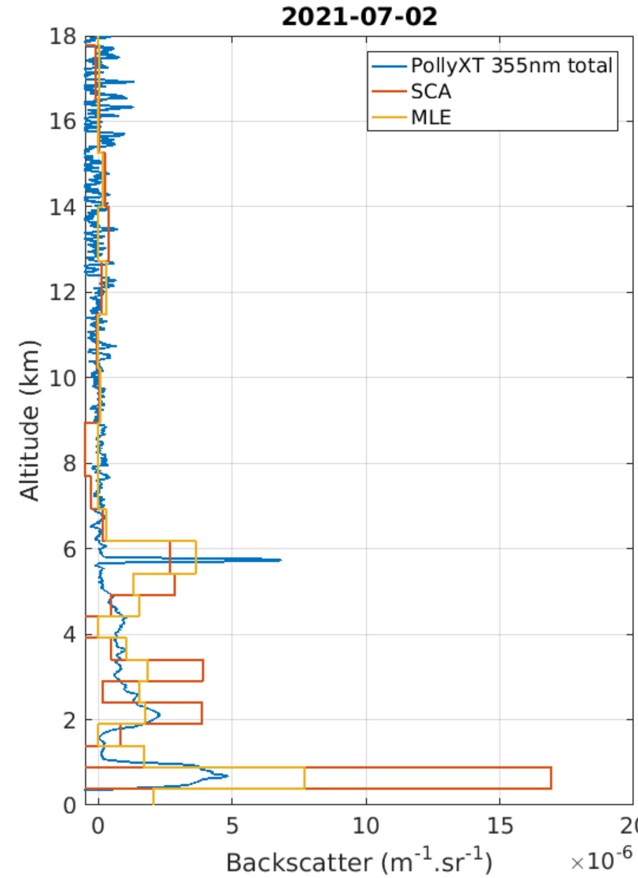




4) Example of L2A output : Intercomparison at Mindelo (Capo Verde) :

- Since July 2021, on-going validation campaign at cape Verde.
- The comparison with the ground observation seems good and MLE results are encouraging.

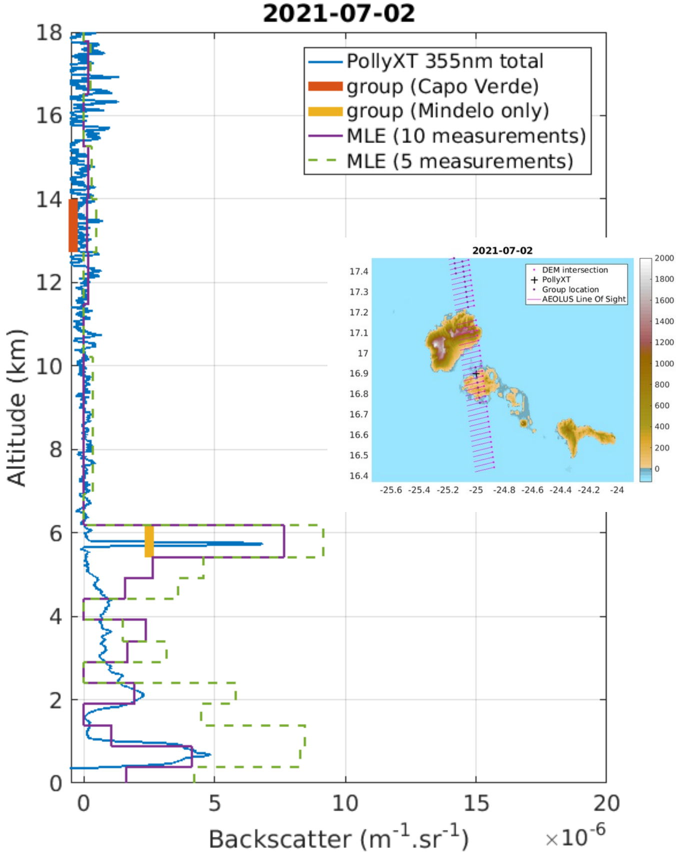




Comparison of the retrieved backscatter between the ground lidar PollyXT and the coefficients retrieved by the SCA and the MLE

5) Summary and Future evolutions

- The L2A products (v3.12) are available to the public.
- Validation campaign at Mindelo gives encouraging results.
- On-going development :
  - Finalizing the MLE implementation.
  - Provides product with higher horizontal resolution :
    - Group product or ..
    - MLE sub-BRC



Comparison of the retrieved backscatter between PollyXT and the coefficients retrieved by the group algorithm and the MLE wuth sub-BRC horizontal resolutions.

References

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