Koninklijk Nederlands
Meteorologisch Instituut
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TROPOS

ATLID cloud/aerosol retrieval approaches applied to ALADIN

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Detection of "Strong" features at high resolution

↓

Smoothing of non-cloud returns

↓

Retrieval of aerosol and "thin" ice cloud and extinction and backscatter at low hor. resolution.

↓

High Hor. resolution Retrieval of extinction and backscatter using OE based procedure (S from step above is used as a priori info.)

Outline

- Retrieval of extinction and backscatter
  - What are the issues?
- Outline of ATLID inspired approach applied to Aeolus.
- Examples including trial comparison with ground-based lidar.
- Conclusions/outlook

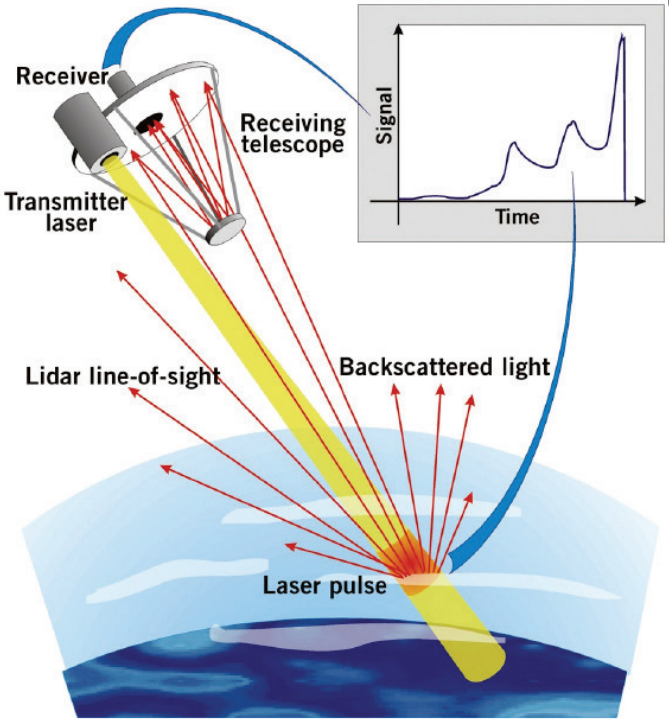
Power

$$P(z=\frac{ct}{2})=\frac{C}{z^2}\left(\beta_{Ray}(z)+\beta_{Mie}\right)\exp\left[-2\int_0^z\left(\alpha_{Ray}(z')+\alpha_{Mie}(z')\right)dz'\right]$$

Attenuated backscatter

$$ATB=\frac{1}{C}z^2P(z)=P(z=\frac{ct}{2})=\left(\beta_{Ray}(z)+\beta_{Mie}\right)T^2(0,z)$$

$$\begin{pmatrix} ATB_{Ray,o} \\ ATB_{Mie,o} \end{pmatrix}=\begin{pmatrix} K_{Ray} & 0 \\ 0 & K_{Mie} \end{pmatrix}\begin{pmatrix} C_1 & C_2 \\ C_3 & C_4 \end{pmatrix}\begin{pmatrix} ATB_{Ray} \\ ATB_{Mie} \end{pmatrix}$$



Invert

Profiles of the "True" separate Rayleigh and Mie attenuated backscatters

IF high enough SNR extinction and backscatter can be directly derived !

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The Essential problem…

- Space-borne lidar signals are noisy !
- To take advantage of the HSRL lidars capabilities a decent SNR is required.
- Along-track averaging to increase the SNR is one solution. However one can not mix “strong” (e.g. cloud) and “weak”(e.g. aerosols) and returns and hope to get anything quantitatively useful !

What is currently Done

- The official L2a retrieval algorithm the ``Standard Correct Algorithm (SCA)'' is (fundamentally) a variation of the normal derivative approach for deriving extinction. (some alterations for accounting for low altitude resolution)

- It has high SNR requirements.
  - Extinction –to-backscatter ratios very noisy !
  - Uses observation level averaging as default.

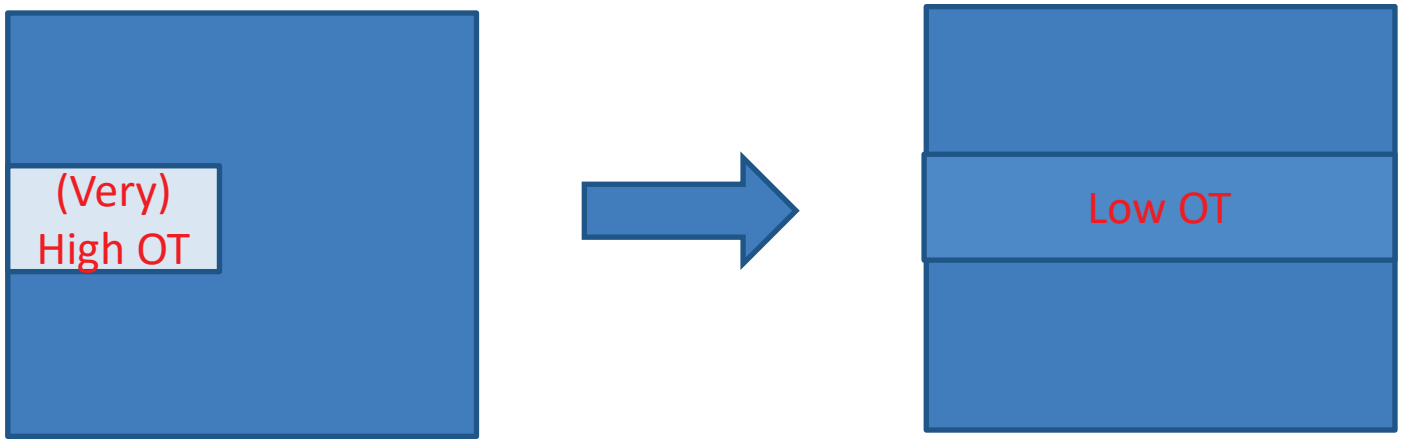
- No handling of MS effects.

- Main product does not screen before averaging !

- Does not make optimal use of all available info.

Note on averaging

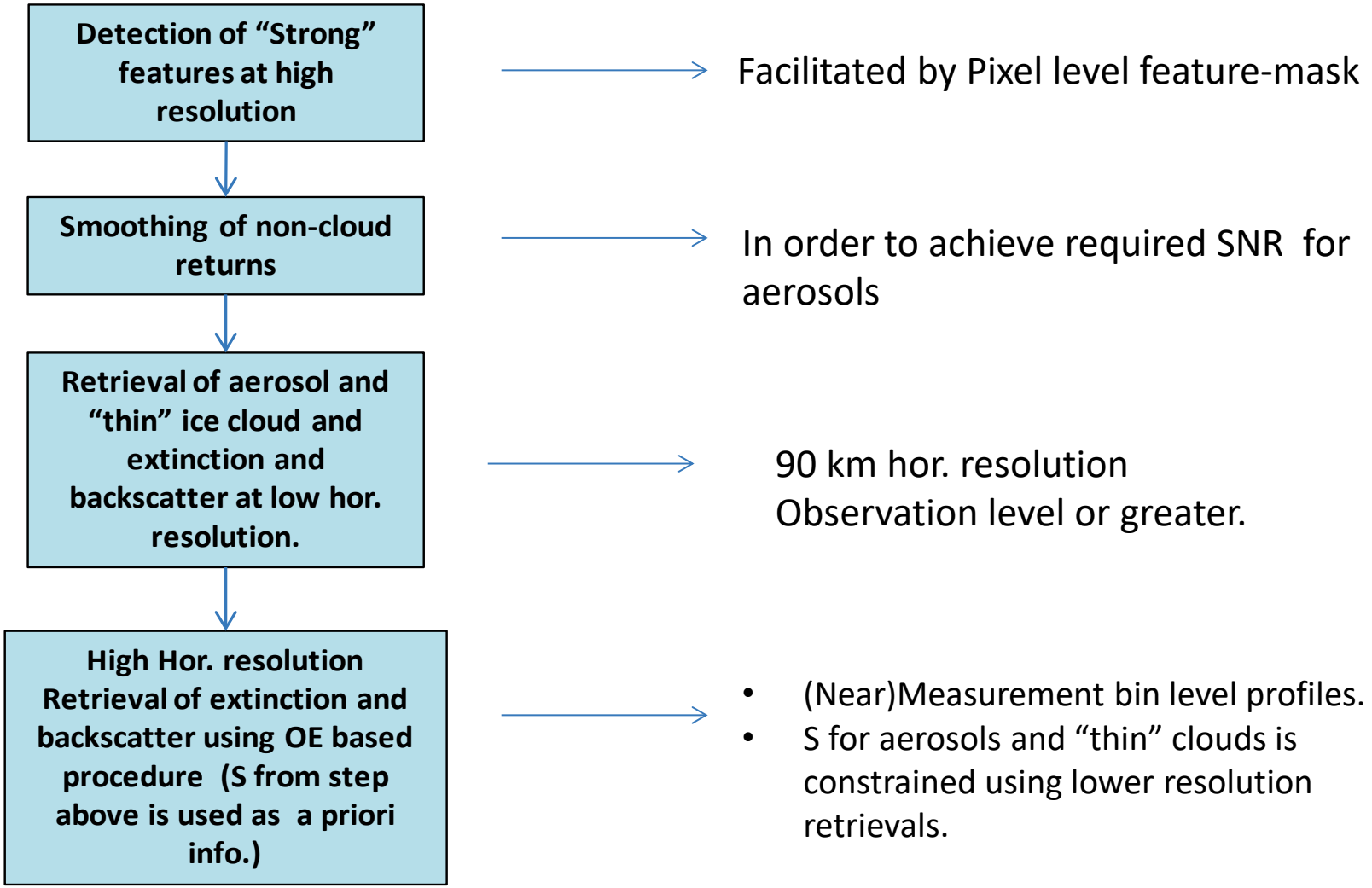
- Mixing of strong (e.g. cloud) and weak (e.g. aerosol) returns is NOT desirable.
- Cloud returns get blurred out !
- Extinction profiles can become meaningless.



- Averaging must be done in a smart manner !
- One also needs a ``solver'' that works at high-hor. res.

Donovan et al., EGU, 2020

Since clouds and aerosols are variable on different scales and A multi-scale approach should be used ! (e.g.)



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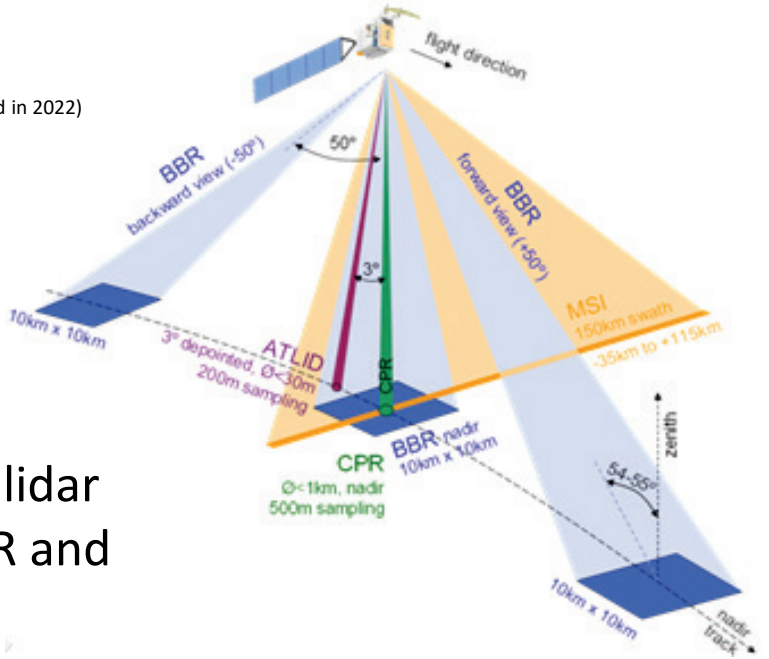
Lessons from EarthCARE Developments

- Earth Clouds and Radiation Explorer (to be launched in 2022)
  - One of the 4 instruments is a HSRL Lidar.
  - Focused on Cloud and Aerosol Retrievals !



- Approaches being developed for the EarthCARE lidar (ATLID) specifically address the issues of low SNR and intelligent binning/averaging.

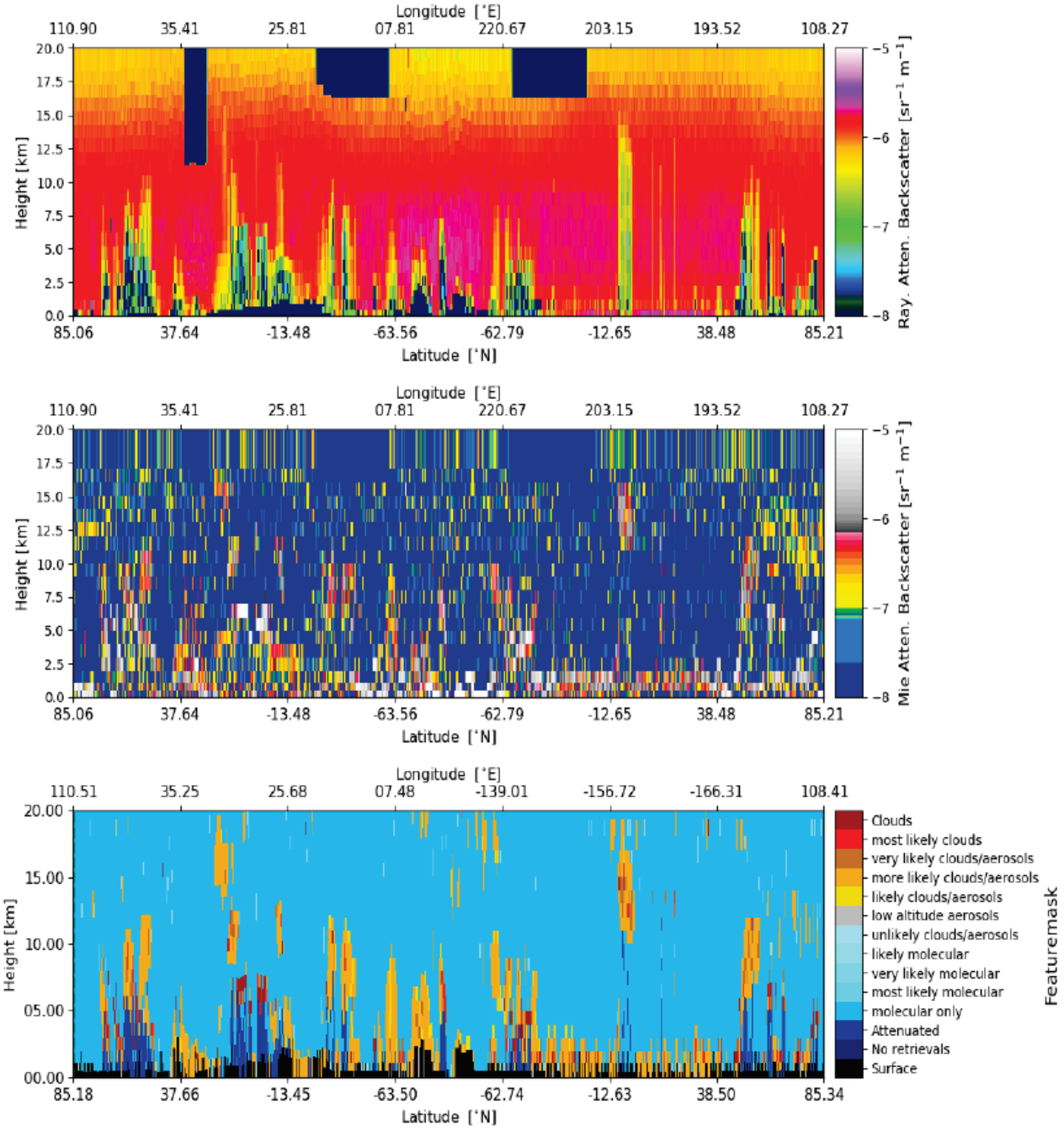
- Ideas (and even code) from ATLID Feature-Mask (A-FM) and the Profile processor (A-PRO) have been adapted to Aeolus .

Step 1: ATLID-Featuremask (A-FM)

- Provides a mask on the highest resolution possible. This facilitated adaptable binning/averaging strategies.

- Uses image processing ideas to identify features in the signals.
  - Edge preserving filter (Hybrid median) to detect strong features.
  - Iterative smoothing together with signal probability histogram analysis in order to detect weak signal areas.

- Variable height grid presents issues for the algorithm
  - Recent work has focused on transforming to and from a uniform grid.
    - Noise must also be homogenized /adjusted when going to higher resolution grid.



AE_OPER_ALD_U_N_2A_20190914T033547026_005412006_006141_0001_xtal

Example of A-FM adapted to Aeolus cross-talk corrected signals

Step-2: Optimal Estimation approach for extinction and Lidar-ratio retrievals.

- SCA(-like) method are not very well-suited for taking advantage of a multi-scale approach.

- A solver than can be reliably applied at measurement level is required.

- Thus, an optimal estimation (OE)approach “inspired” by the A-PRO ATLID approach has been applied to Aeolus.

Development of a OE based solver. That can be applied at different hor. resolutions (down to measurement level).

$$\chi^2 = [(Y_i - y_i)]\left[C_{i,j}\right]^{-1}[(Y_i - y_i)]^t + \left[(X_{i_a} - x_{i_a})\right]\left[C_{a,i_a,j_a}\right]^{-1}\left[(X_{i_a} - x_{i,a})\right]^t$$

$$y = observations = (ATB_{Ray_1} .....ATB_{Ray_{nz}}, ATB_{Mie_1} ....ATB_{Mie_{nz}})$$

$$Y = Y(x) = \ forward \ \ modelled \ \ observations$$

$$x = \log state \ \ \text{var} iables = \log(\alpha_1 .....\alpha_{nz}, S_1 ....S_{nz}, Ra_1 .....Ra_{nz}, C_{lid})$$

$$X_a = apriori \ values = \log(S_{a,1} ....S_{a,nz}, Ra_{a,1} .....Ra_{a,nz}, C_{lid,a})$$

Effectively no constraint on extinction (other than being positive)

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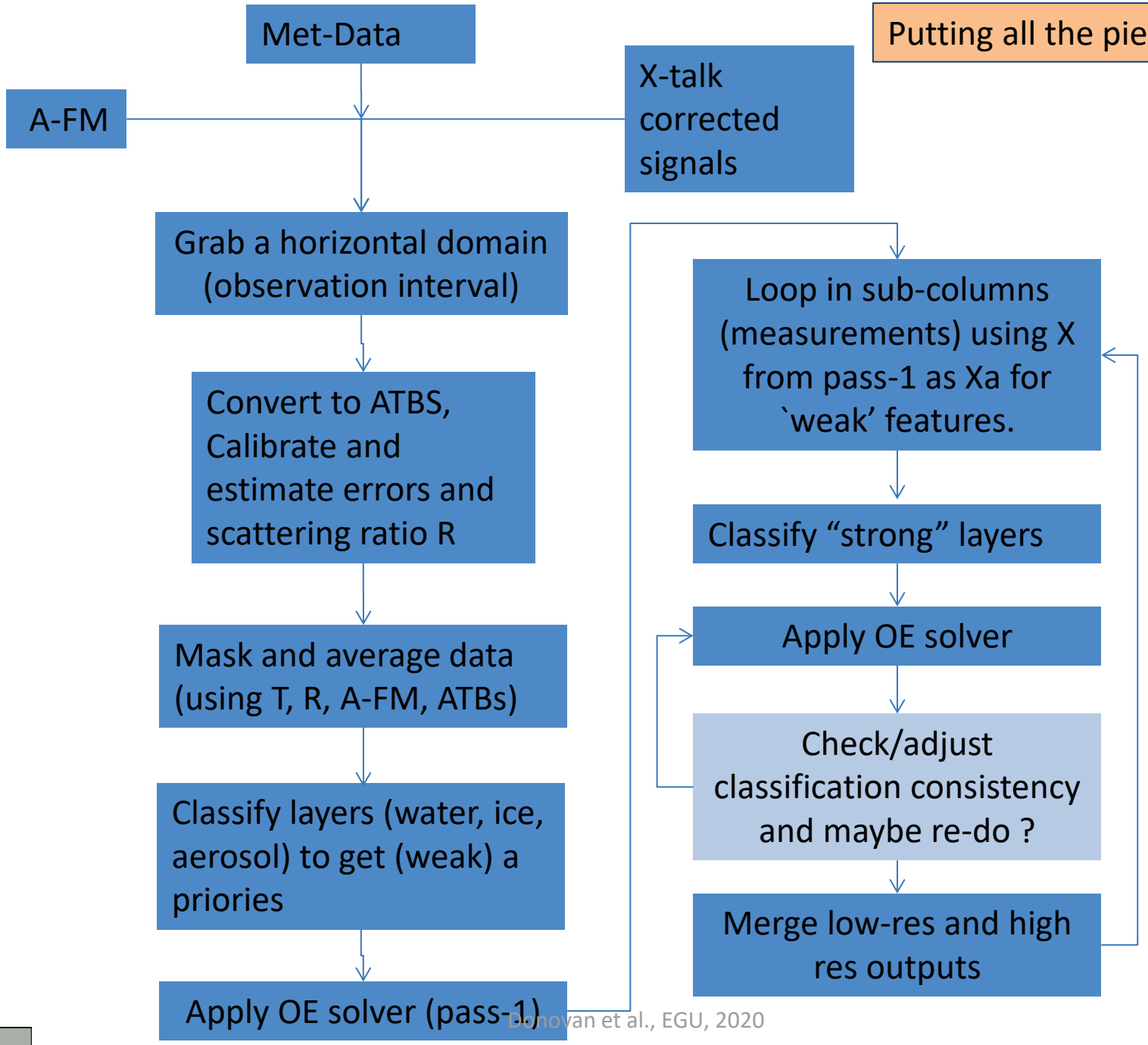
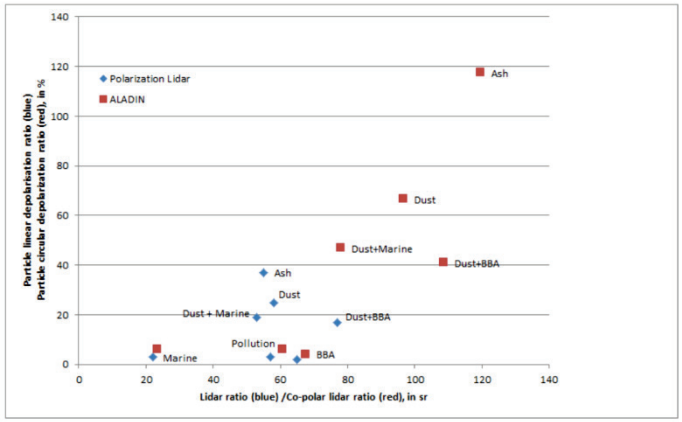
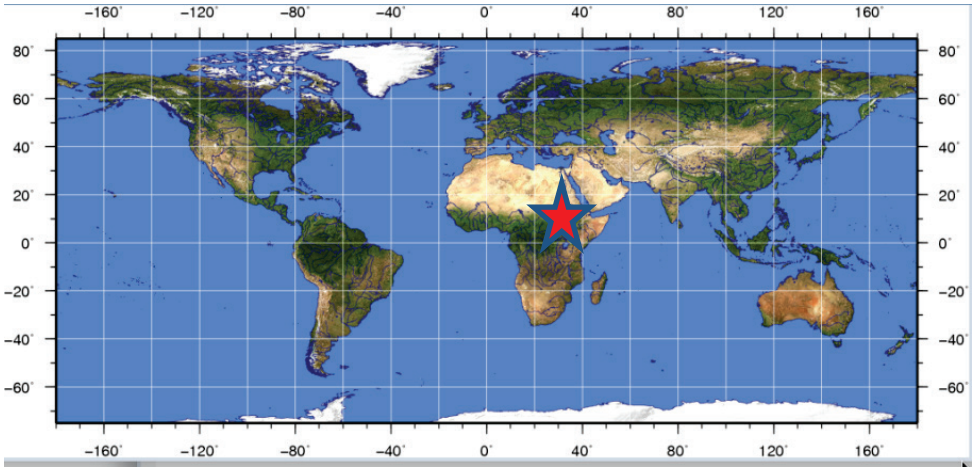
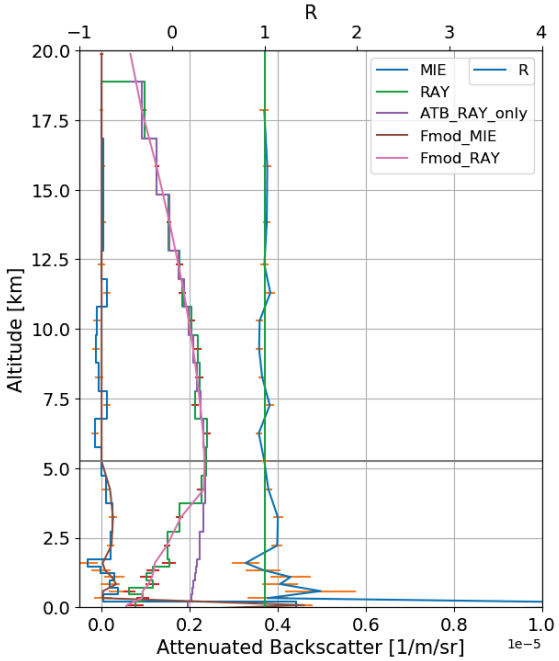
Putting all the pieces together

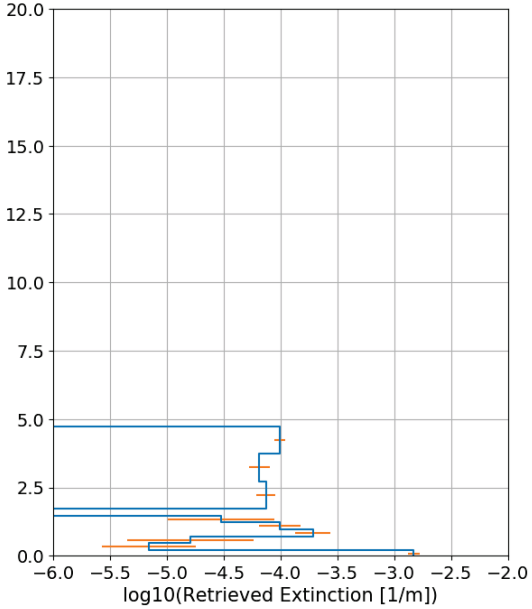


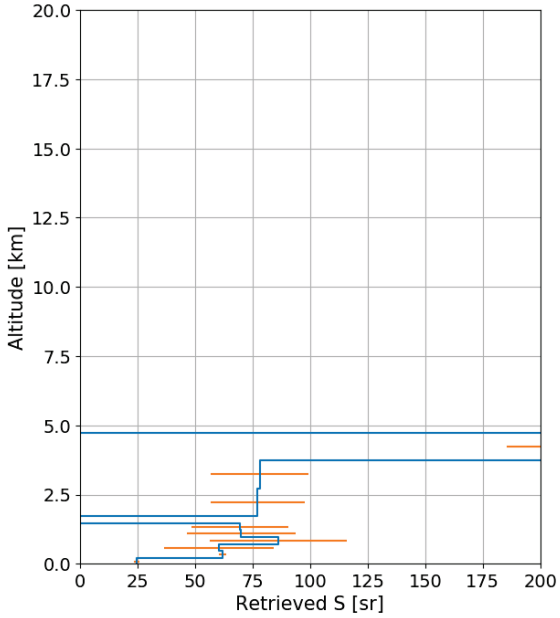
Some Examples-2a











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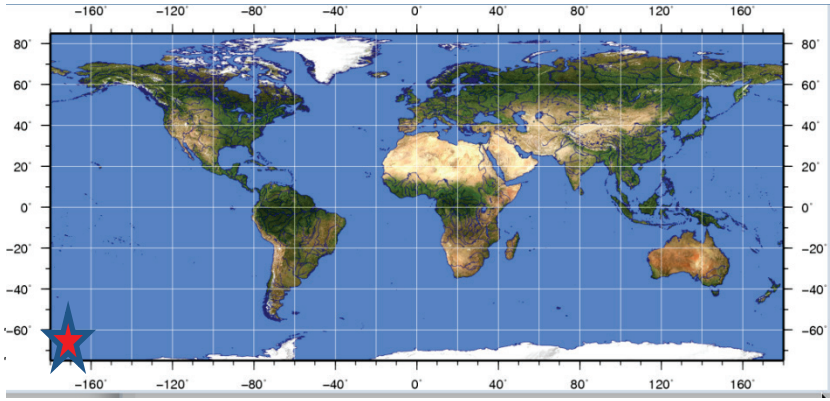
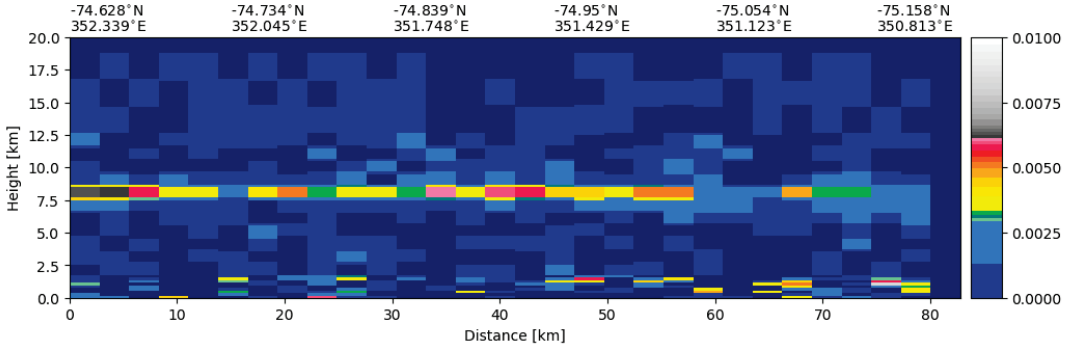
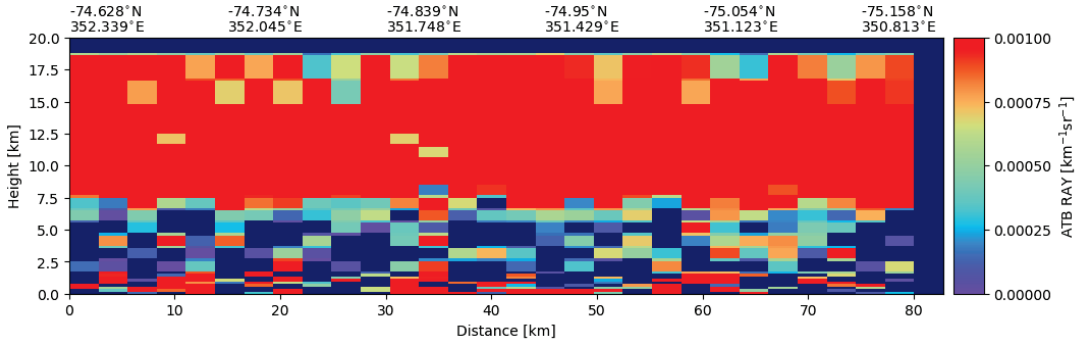
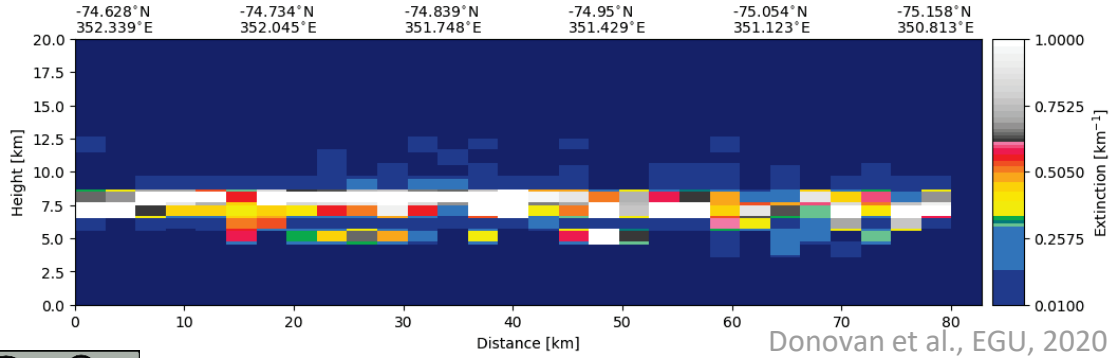
A Cirrus Example









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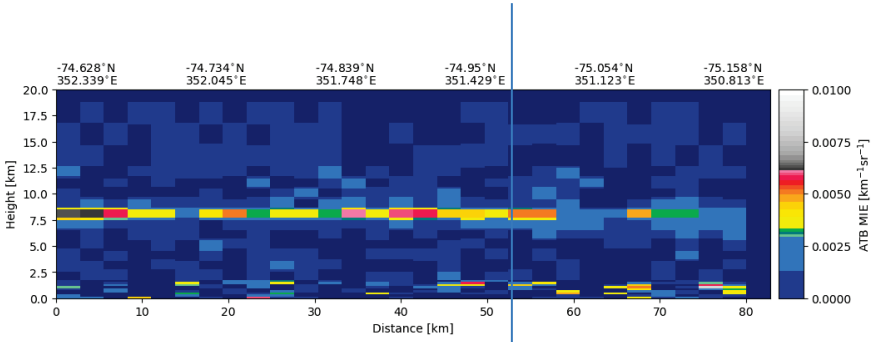
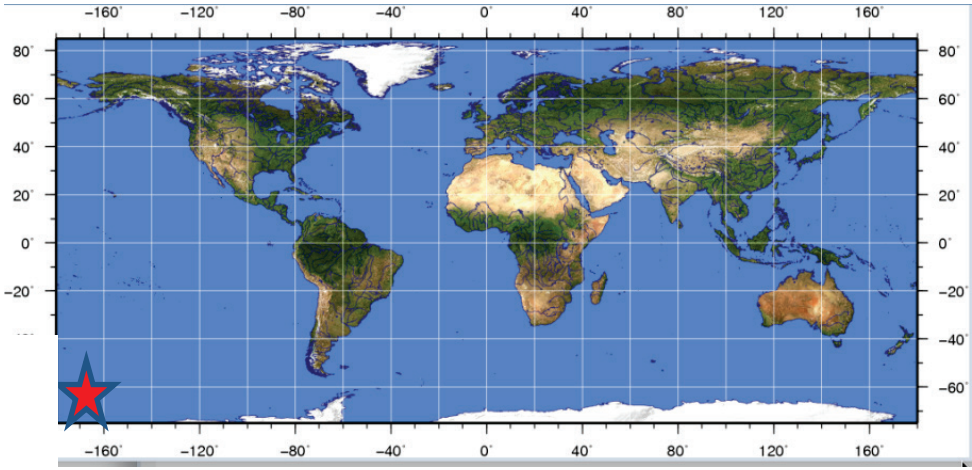
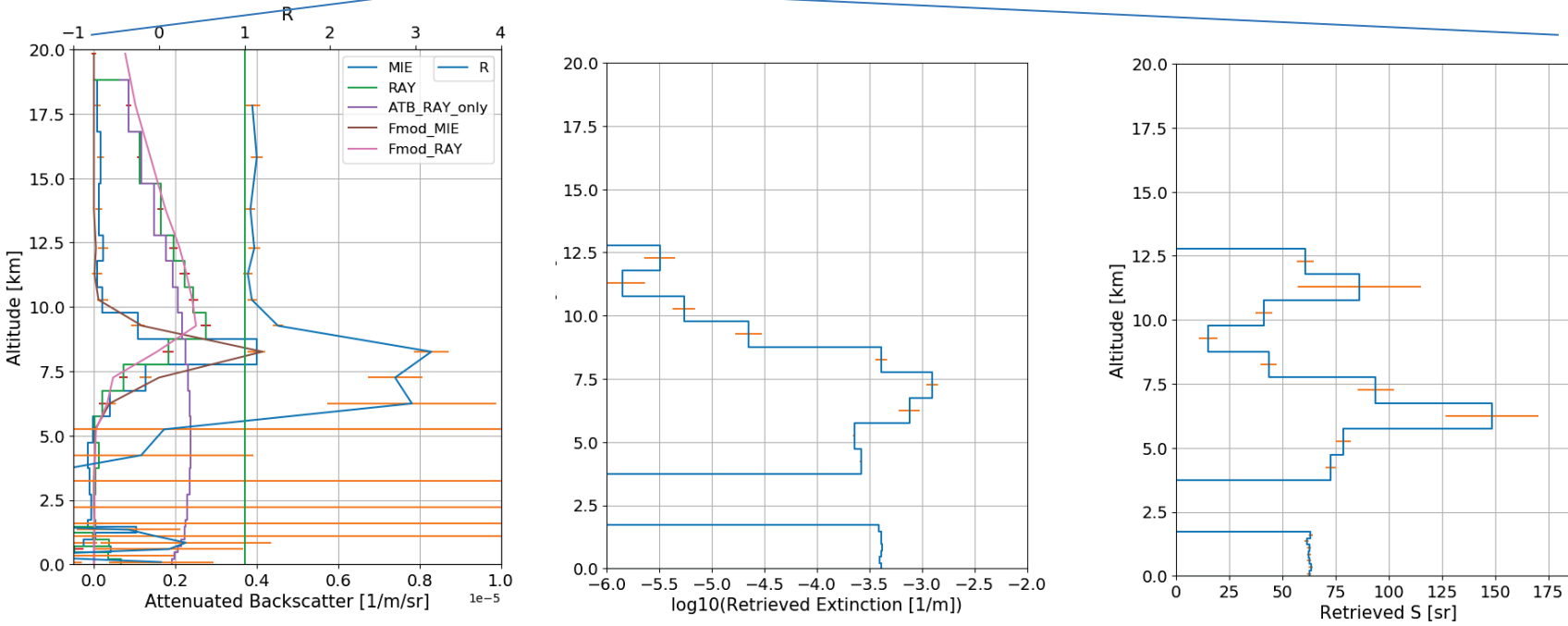
Some Examples-3a

Averaged for 30 profiles







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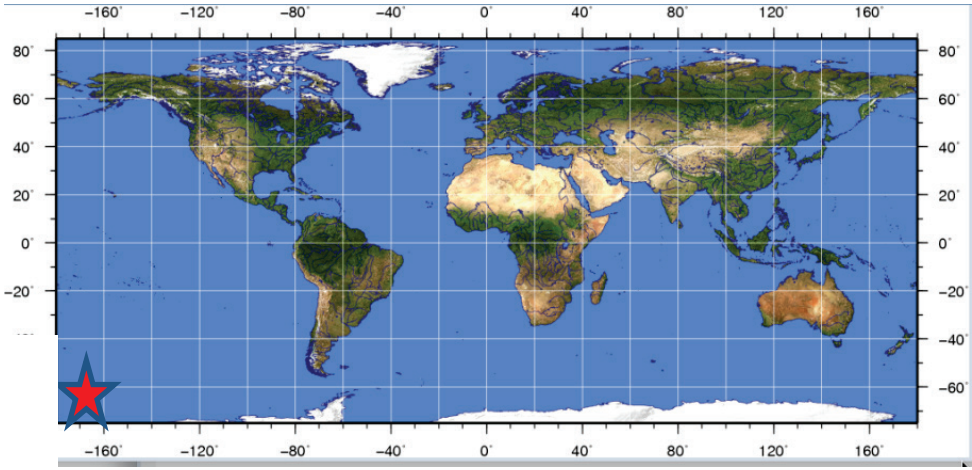
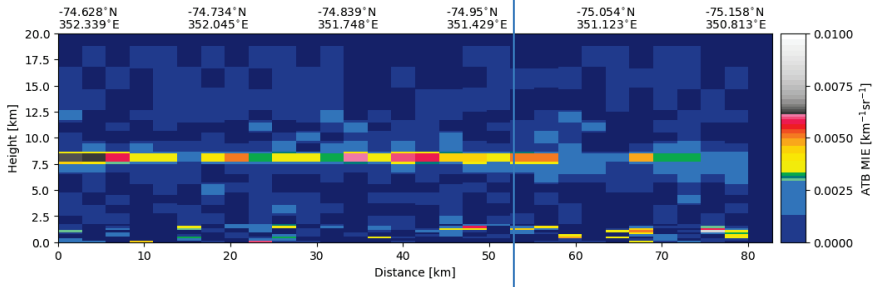
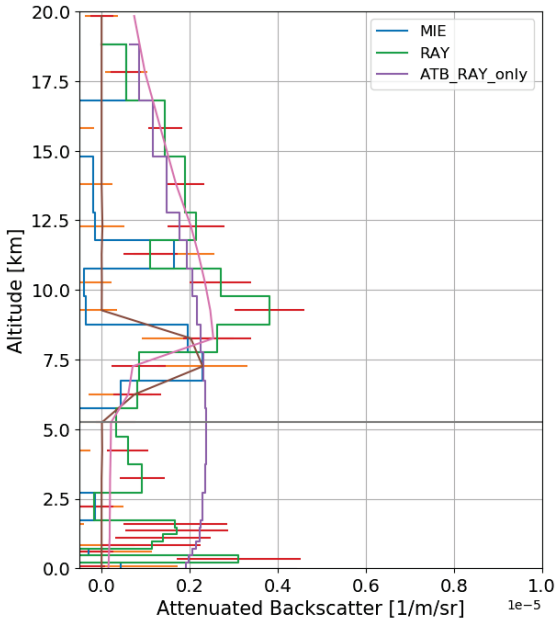
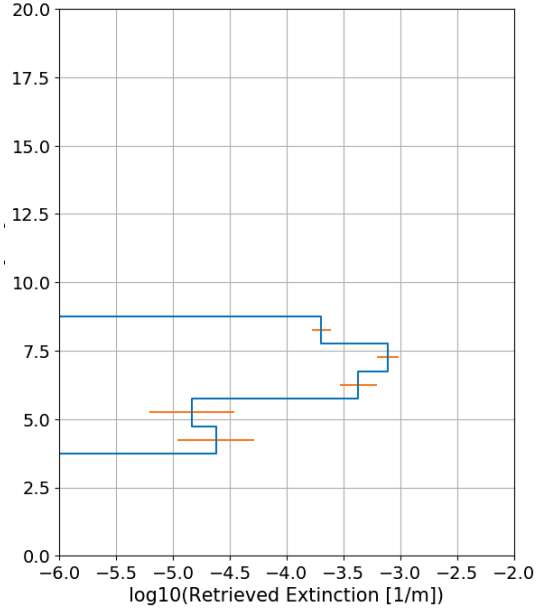
Some Examples-3c

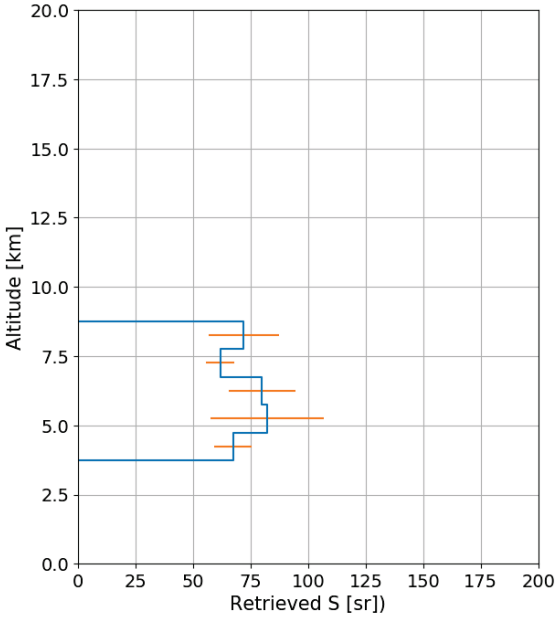
Single measurement profile !











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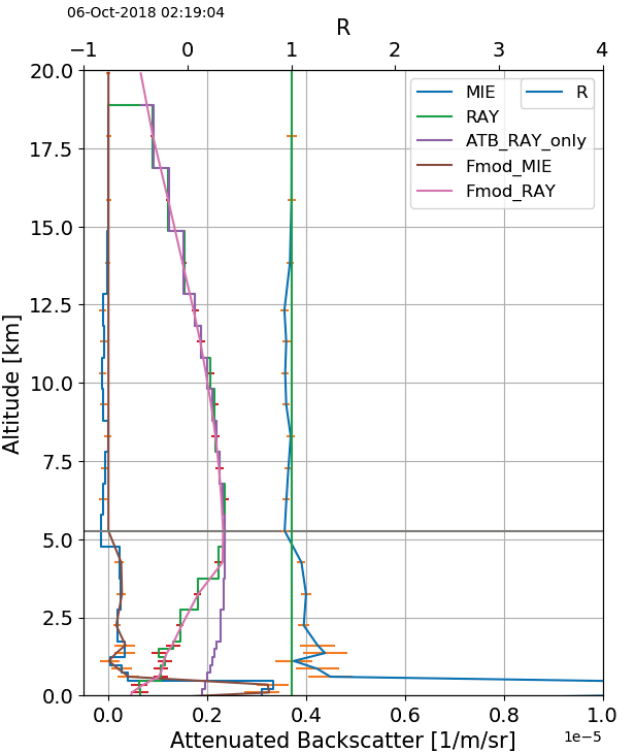
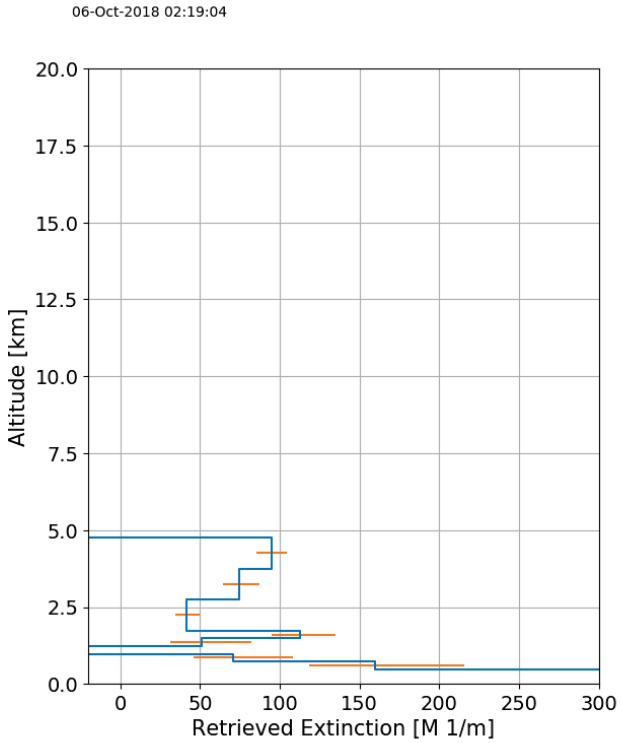
Tests Cases where ground-based Raman Lidar observations exist were chosen for comparison

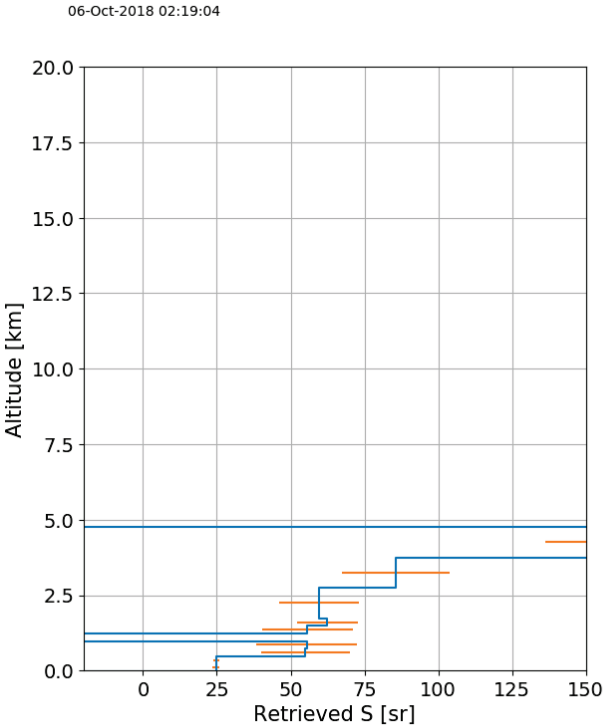
1. AE_OPER_ALD_U_N_2A_20180929T032914035_003587996_000591_0001

2. AE_OPER_ALD_U_N_2A_20181005T234538024_009636001_000699_0001

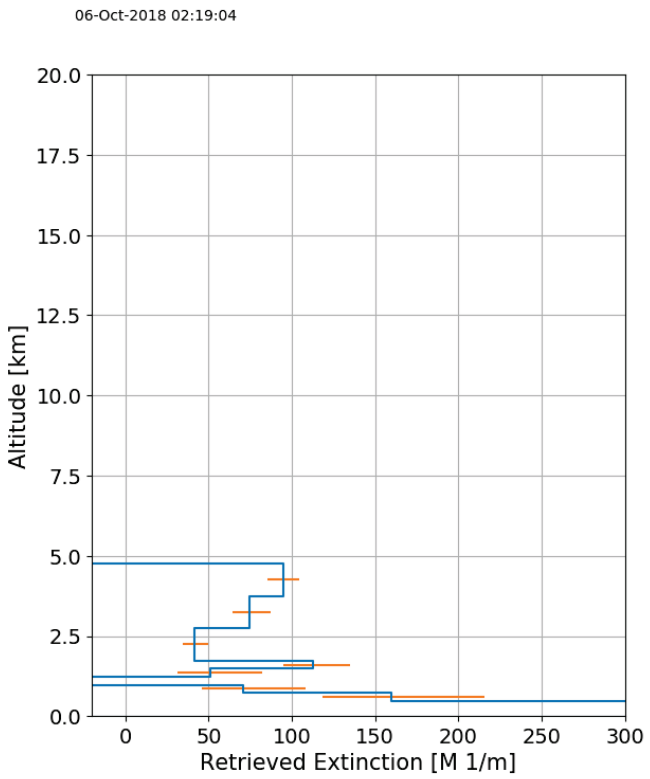
Case-1 (6.10.2018 Al-Dhaid)

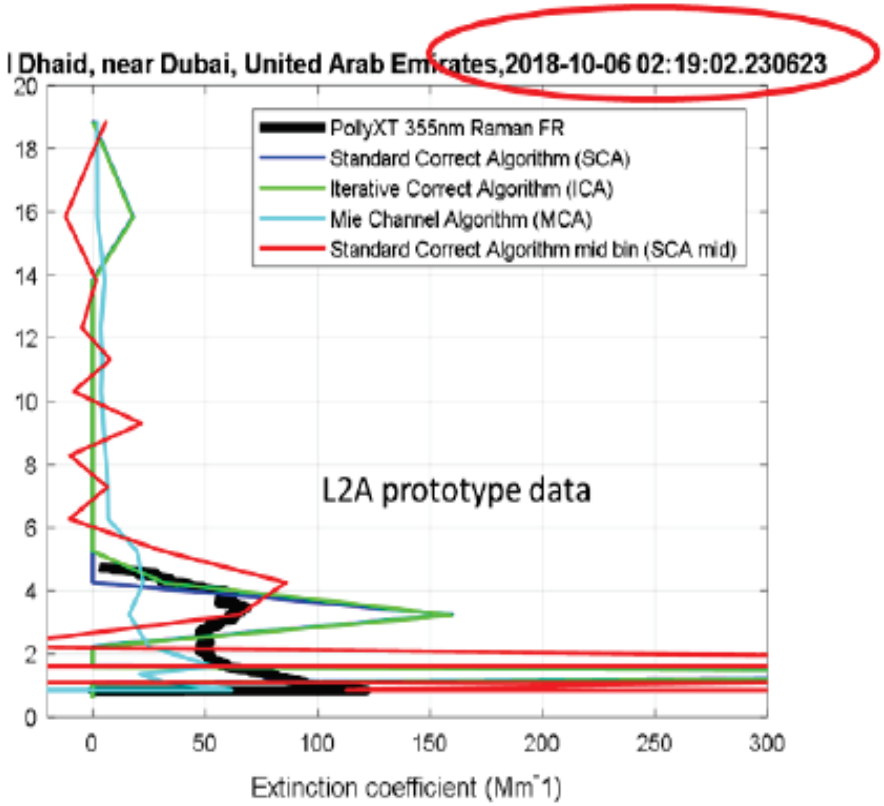






(6.10.2018 Al-Dhaid)





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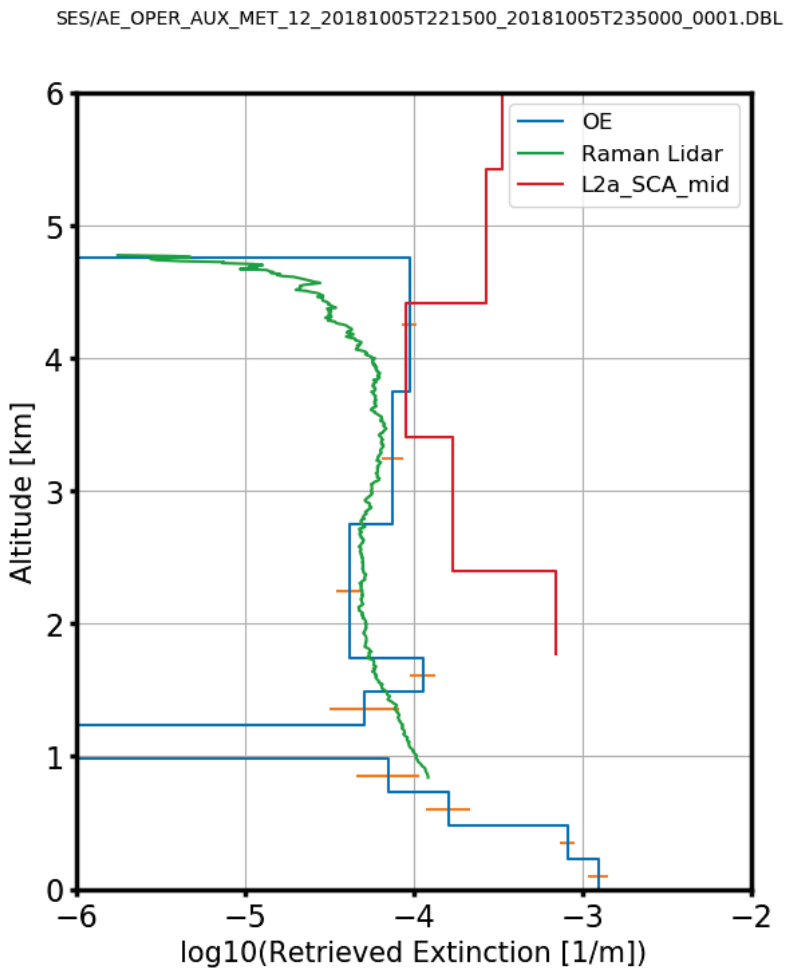
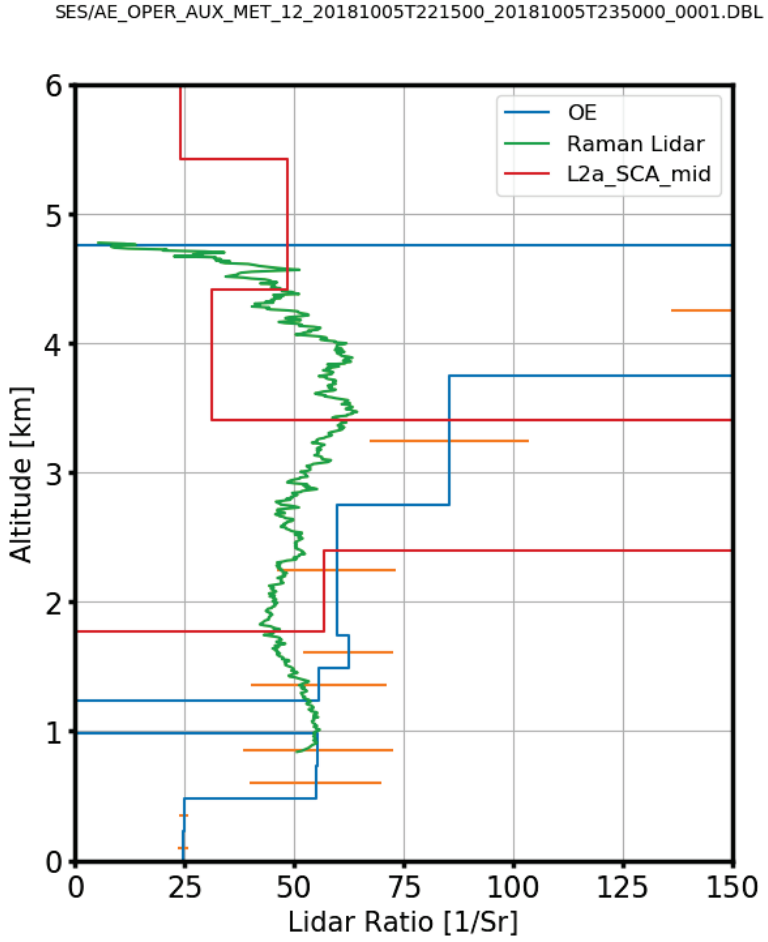
Overestimation of S likely due to too-much Rayleigh signal being removed from the Mie signal during the x-talk correction step.





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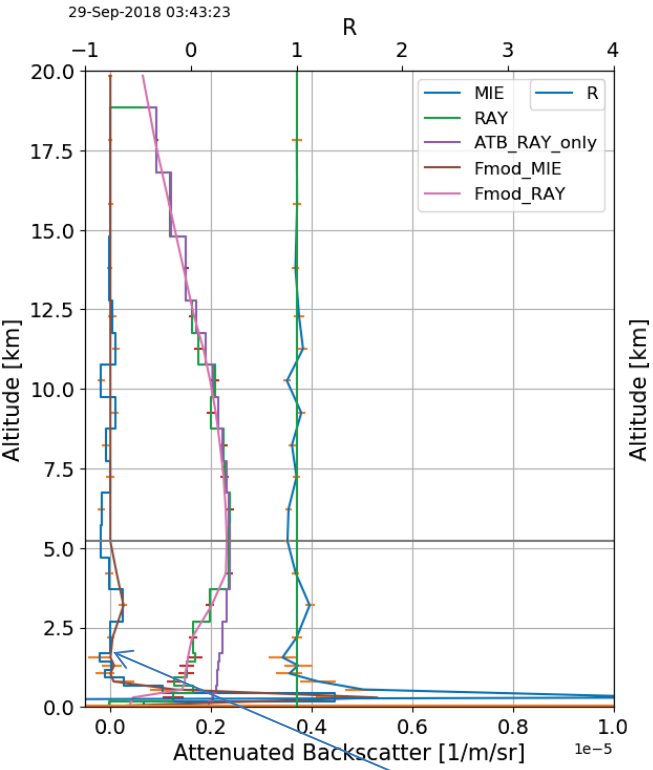

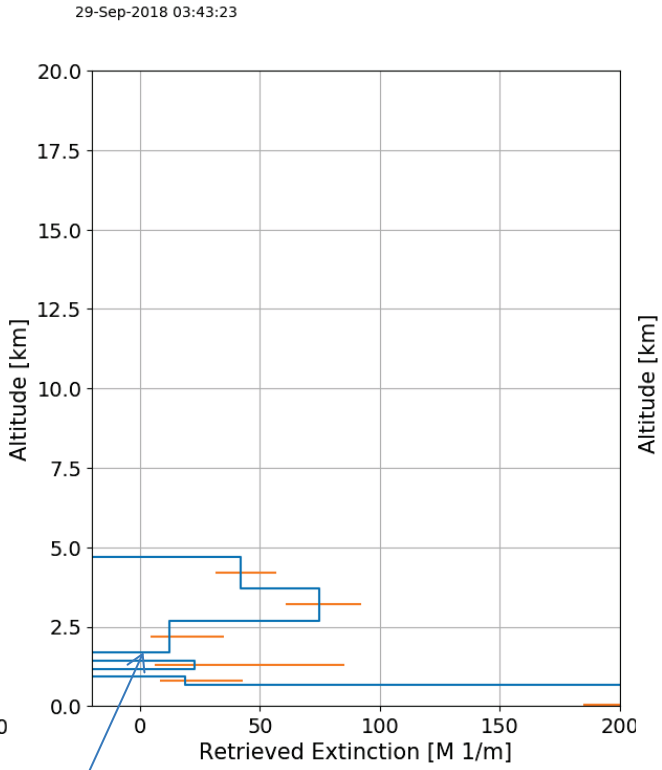

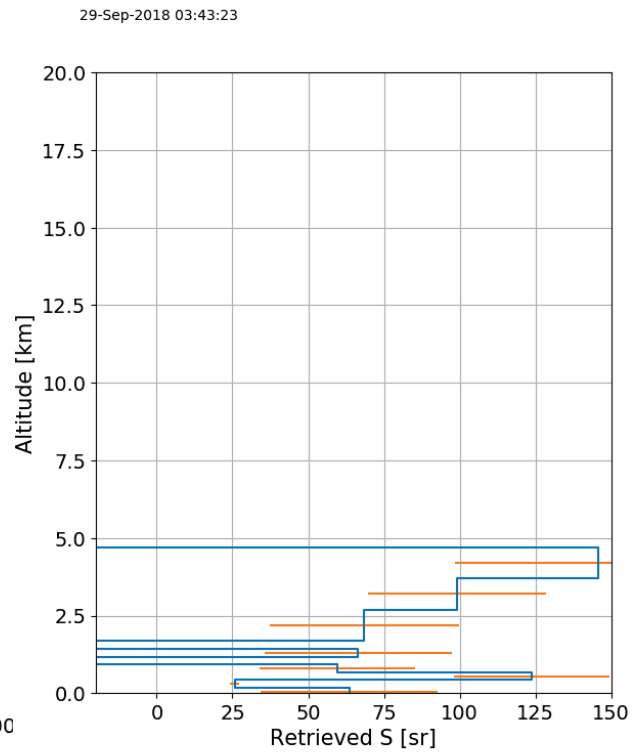

X-talk and/or FM issues ?

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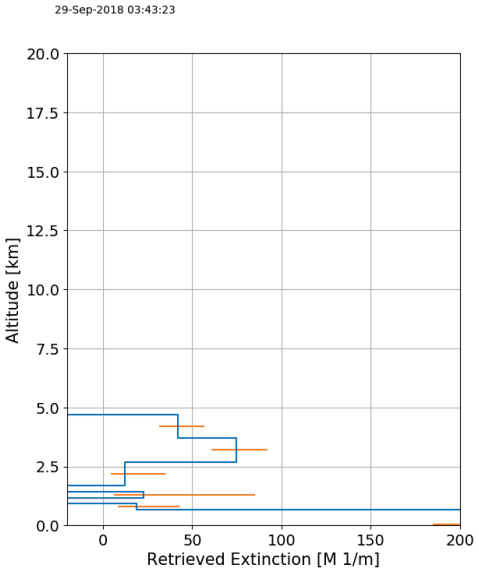
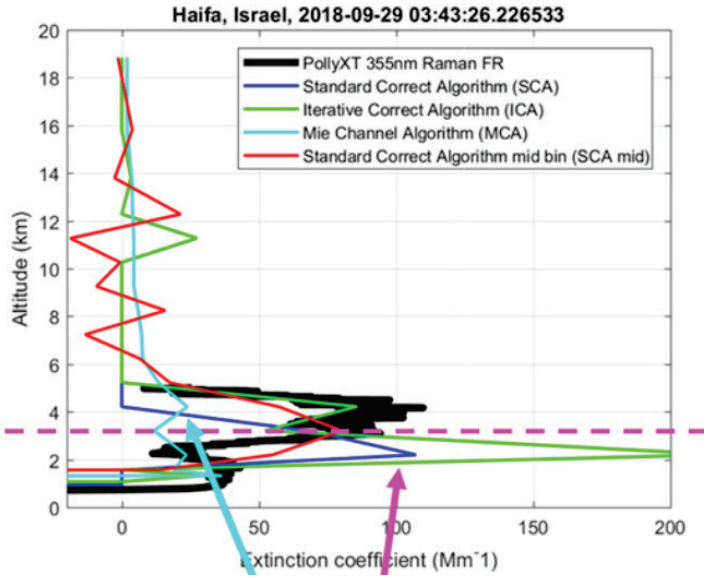
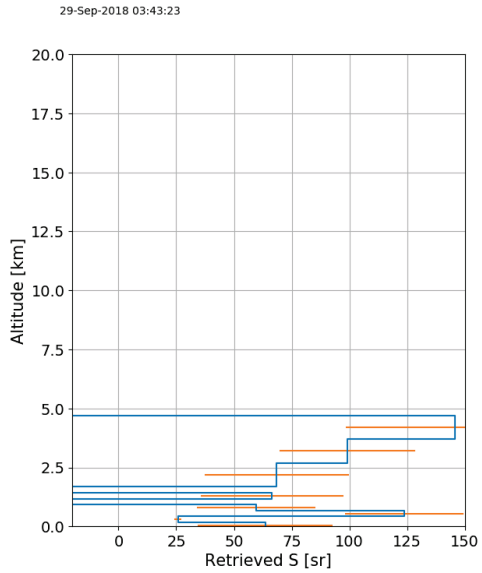
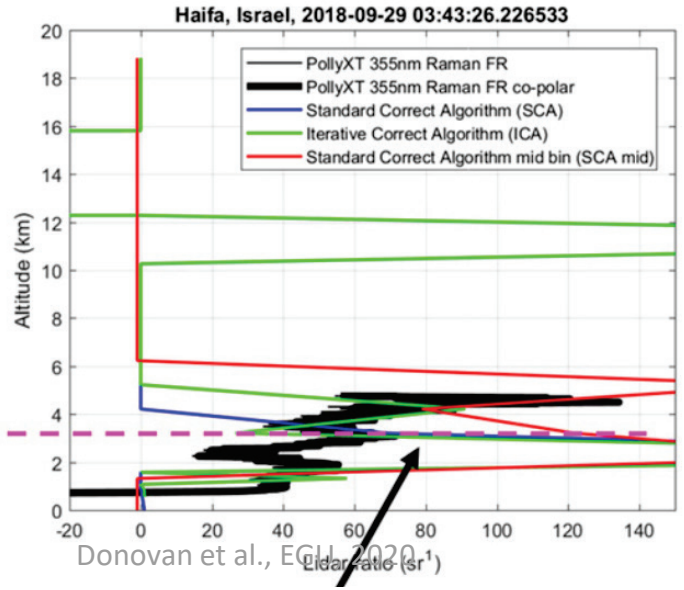


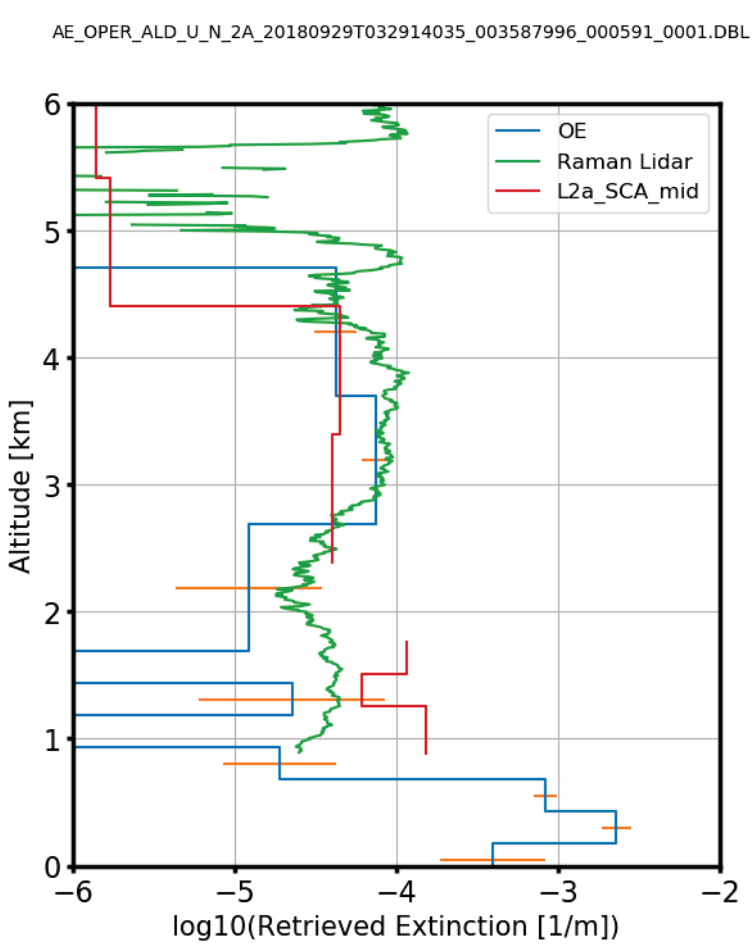


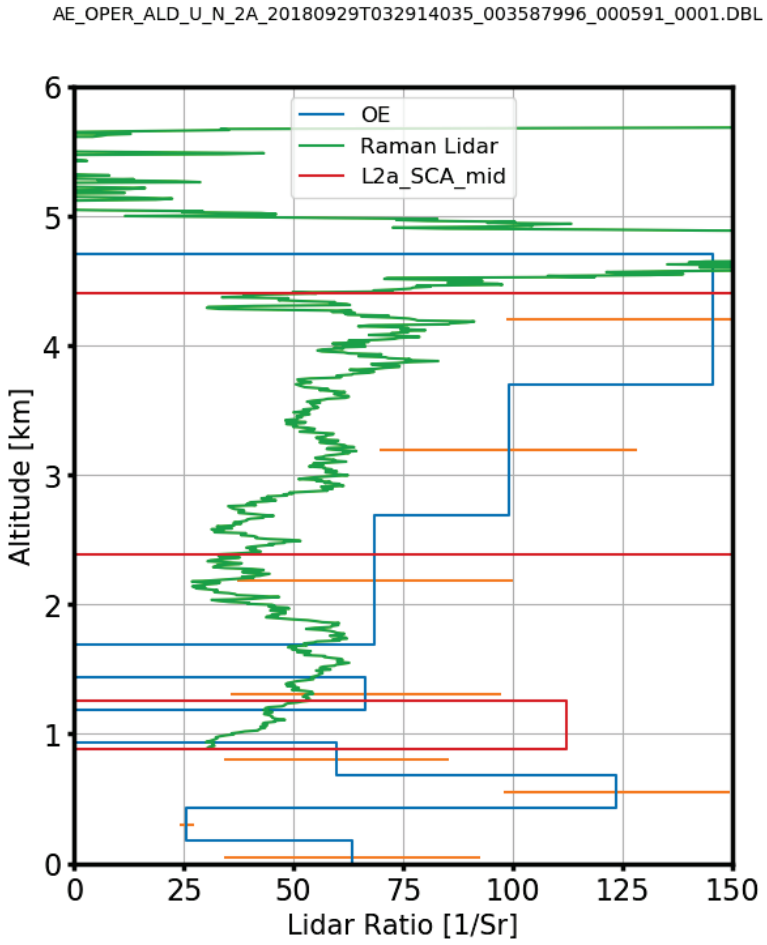




Donovan et al., EGU 2020

Again: Overestimation of S likely due to too-much Rayleigh signal being removed from the Mie signal during the x-talk correction step.





Wrap-Up

- A-FM code has been successfully applied to Aeolus data.
- A prototype (Python/F95-hybrid) OE based procedure using ideas drawn from A-PRO has been developed.
- The procedures appear quite promising.
- Plans for further trials/inter-comparisons have been made !
- Issues noted:
  - Good L1 error estimates needed !
  - The X-talk must be correctly understood !