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TAKING THE PULSE OF OUR PLANET FROM SPACE

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Royal Netherlands Meteorological Institute
Ministry of Infrastructure and Environment

The ATLID L2a featuremask and optical properties profile processors

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KNMI

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Introduction

- Lidar extinction and lidar-ratios from space are not easy retrievals.
  - Low SNR (compared to terrestrial systems) ➔horizontal averaging **but**…
    - The inhomogeneous nature of clouds (and aerosols) ➔high resolution !

- A-FM and A-PRO are two ATLID L2a algorithms that cooperate in order to conduct a multi-scale approach to deliver aerosol and cloud properties.
  - -A-FM: High resolution target mask.
  - -A-PRO: Used A-FM to intelligently average/bin data to provide both aerosol and cloud properties.

Processor	A-FM (ALTID Feature Mask)
Input Products	1. ATLID-L1
Output Products **Brief Description**	1. ATLID Featuremask 2. Retrieved Lidar Surface pixels and detection of temporal gaps in observations 3. Feature Free mean Co/Cross Mie & Rayleigh signals

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Goals:

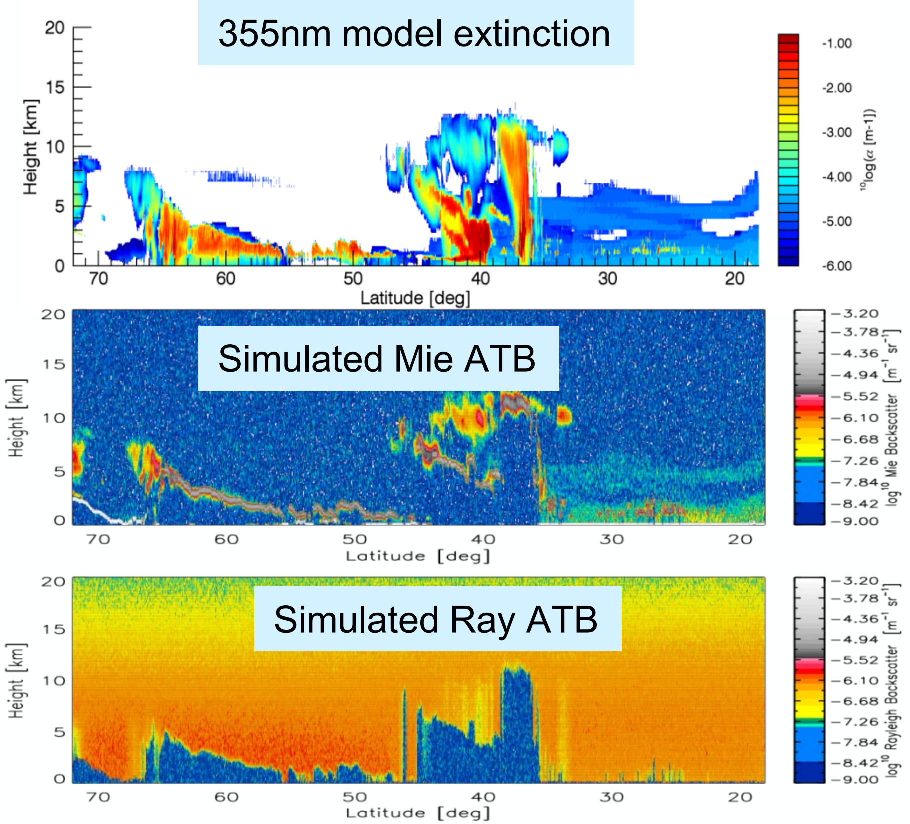
1. Retrieve a mask which detects regions of "significant returns" or "features". No difference between aerosols and clouds is made within the algorithm!
2. Retrieve information on high resolution, preferably a single shot mask, to enable binning strategies to increase SNR of signal (output is on the A-NOM spatial grid)

Calculation Steps:

1. Determine the lidar surface altitude
2. Calculate signal probability based on the measured signals and noise
3. Perform a Median Hybrid calculation to find the strong coherent structures within the image
4. Convolve the remaining signals iteratively to enhance signal to noise ratio.
5. Retrieve low signal features by fitting a Gaussian noise peak to the derived image histogram in order to distinguish signal from noise

ECARE Testing and Development Scenes Derived from Cloud-Resolving NWP model data

- Scenes have been built using ECSIM using Environment Canada’s high-res global NWP model run at 0.25 km hor. res.
- Clouds/precip are handled by a two-mode bulk scheme (Milbrandt-Yau)
- No Aerosols in provided fields ➔ Merge with ECMWF CAMS fields.



Example (Halifax Scene)

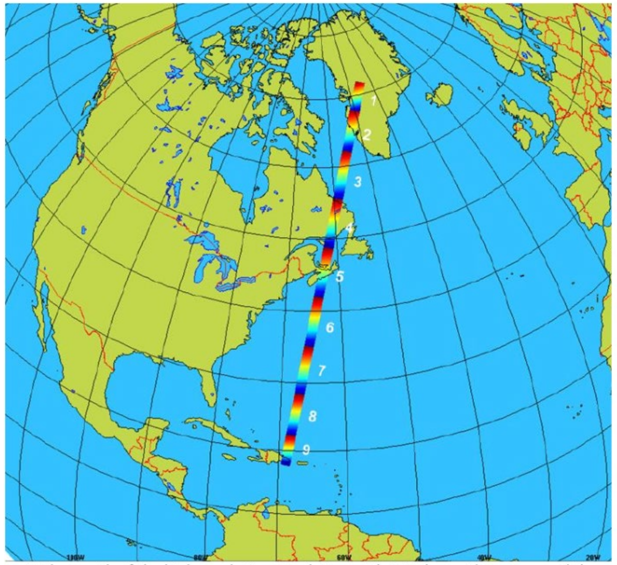
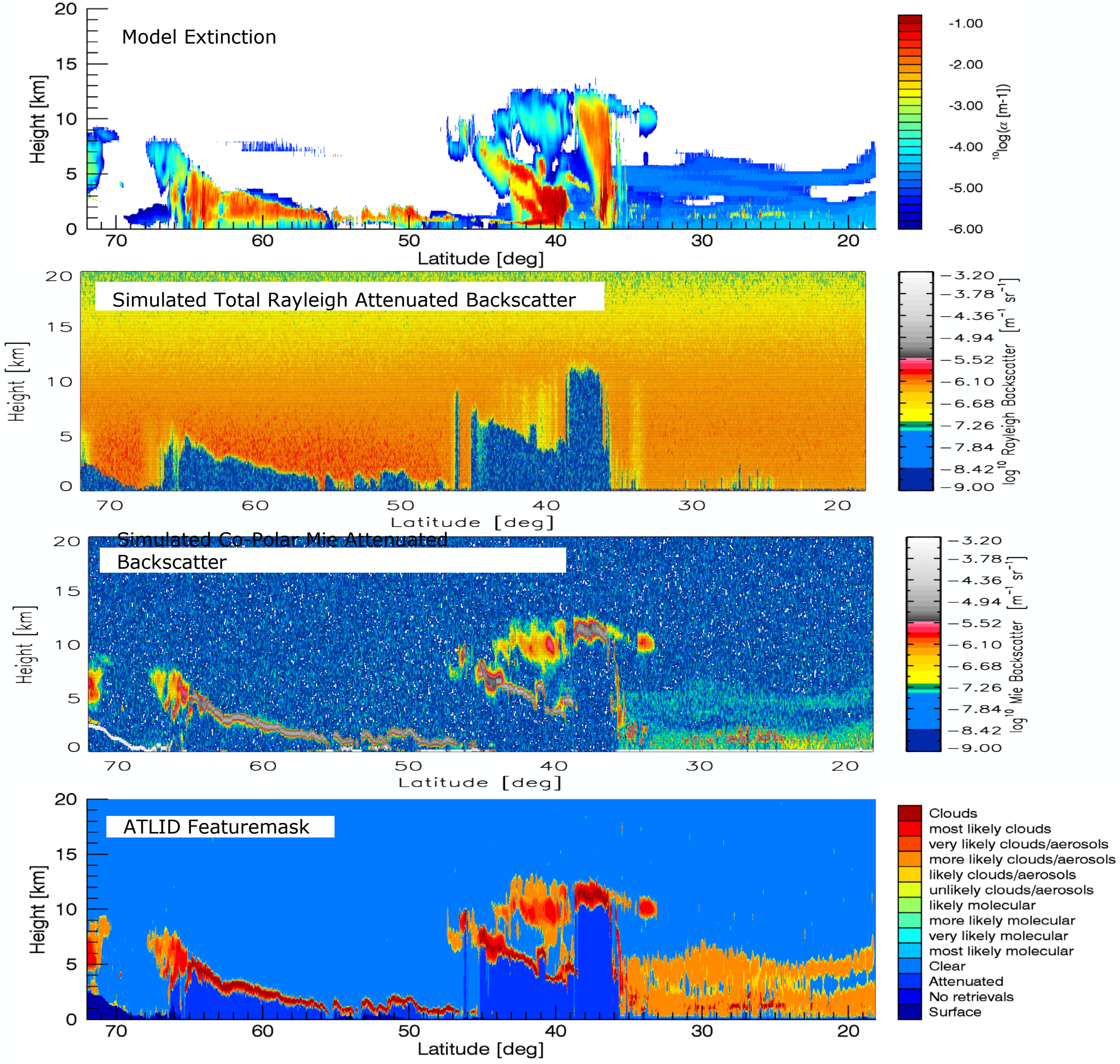
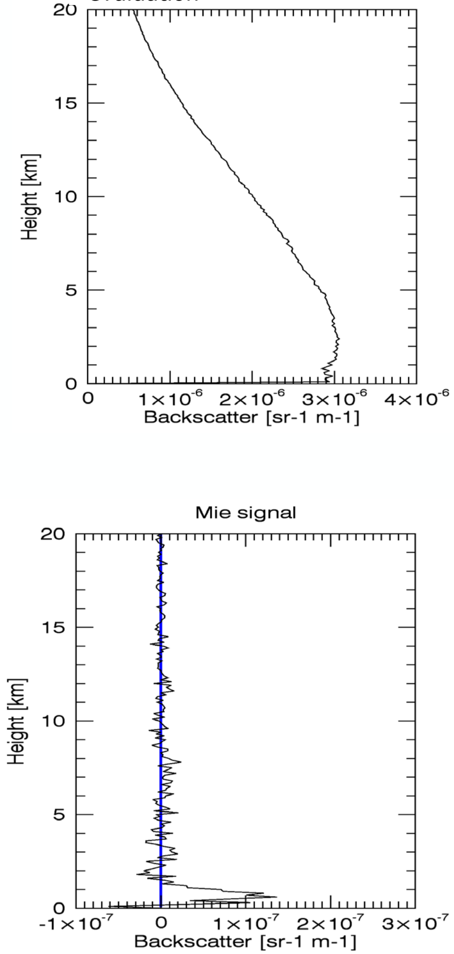


Figure 2: the swath of the high resolution simulation with 0.25 km grid-spacing and the seven section of the separated simulation.

A-FM applied to Halifax Scene



Averaged Attenuated Backscatter signals for feature free regions. Used for L1 calibration and Featuremask evaluation



Processor	A-PRO (ATLID Profile processor)
Input Products	1. FeatureMask 2. ATLID L1 3. Auxiliary Met data
Output Products (reported on Joint standard Grid grid)	1. Aerosol and cloud optical properties. 2. Target Classification 3. Aerosol type

Brief Description

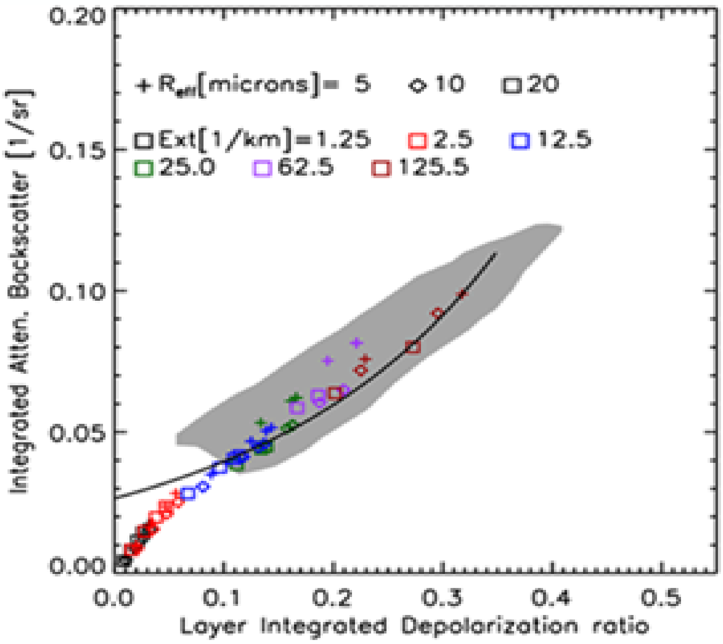
- **Two Step approach to deriving optical properties**:
  1. “Conventional” HSRL techniques applied to smoothed fields.
  2. High resolution OE forward model retrievals aimed at clouds.
- Cloud/aerosol discrimination and aerosol typing based on using Backscatter thresholds as well as S and linear depolarization ratio.
- Cloud phase determination via layer integrated backscatter-vs-integrated depolarization ratio.

1. **Detection of “Strong” features at high resolution**
2. **Smoothing of non-cloud returns**
3. **Direct retrieval of aerosol and “thin” ice cloud and extinction and backscatter at low hor. resolution.**
4. **High Hor. resolution Retrieval of extinction and backscatter using OE based procedure (S from step above is used as a priori info.)**

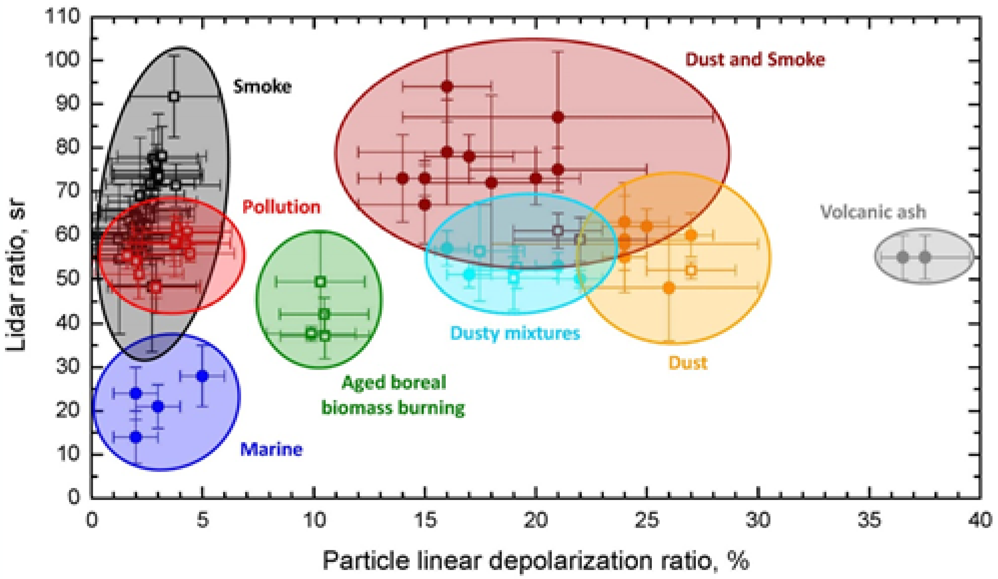
Target Classification (A-TC)

-Cloud/Aerosol separation based on combination of thresholds and, in the case of thin-ice-vs-aerosol, depol. and lidar-ratio

Cloud phase based on integrated depol. -vs-integrated attenuated backscatter

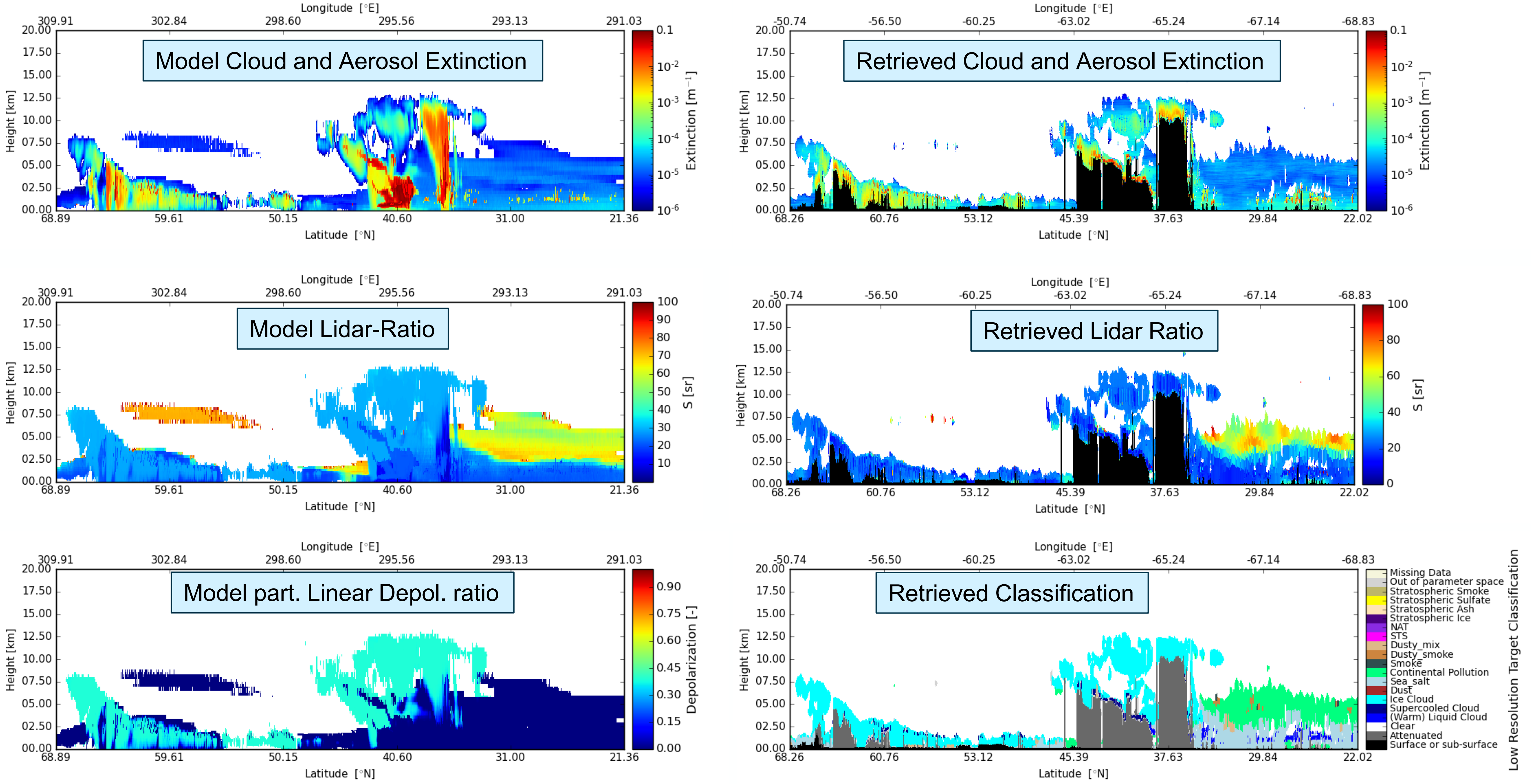


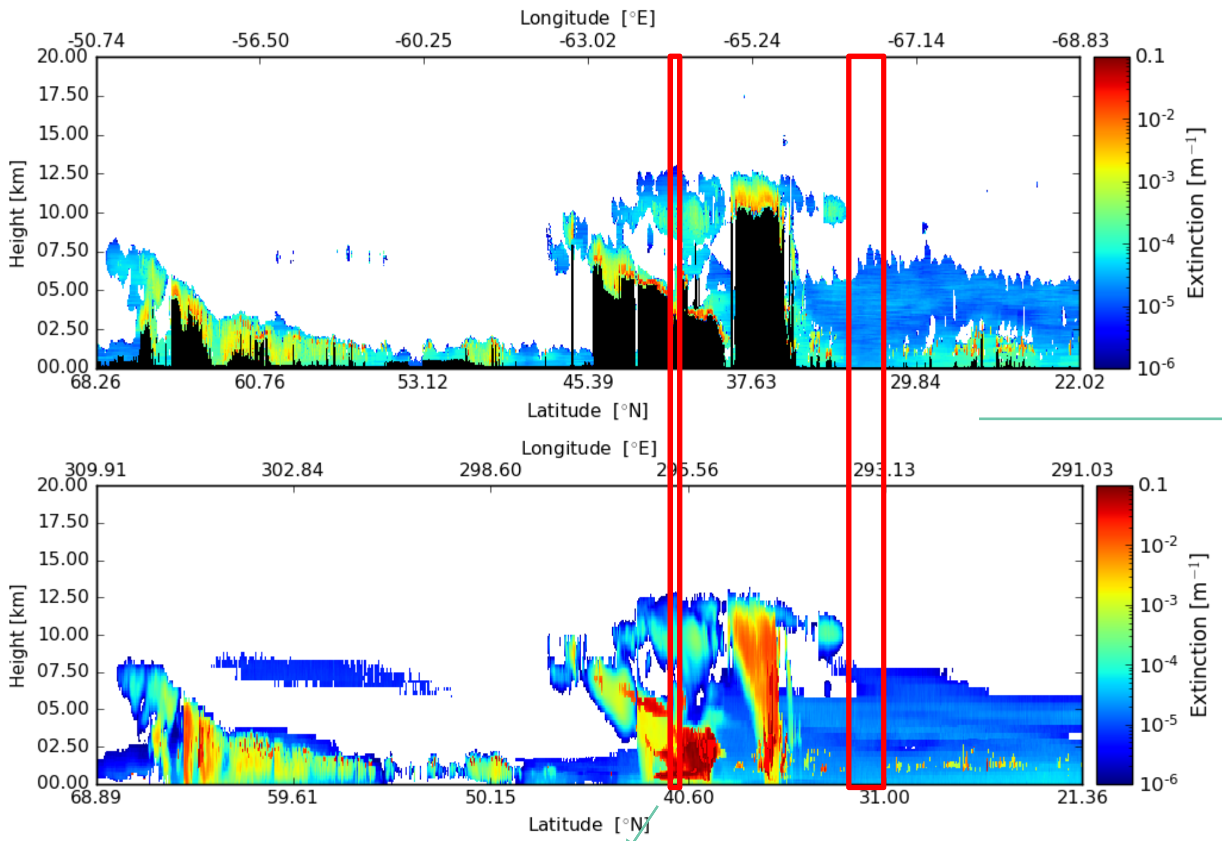
Aerosol type based on depol.-vs-lidar-ratio



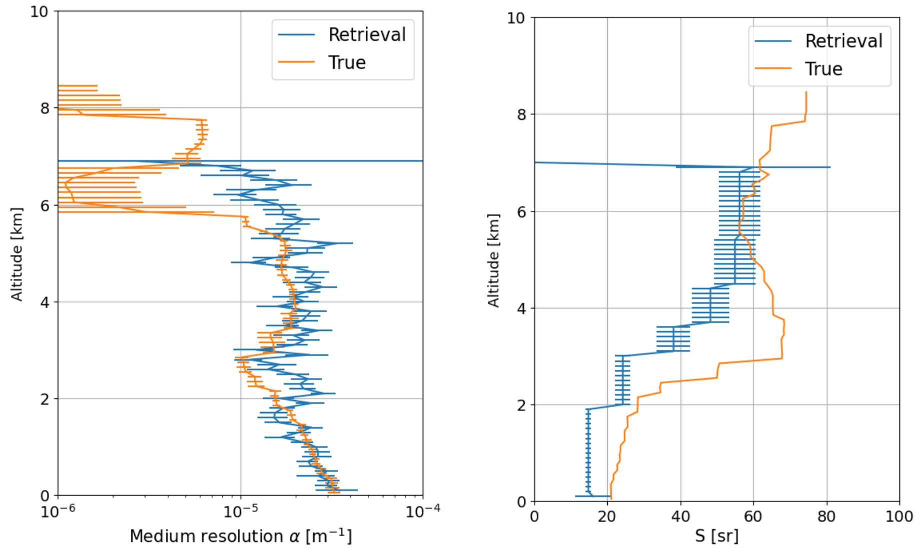
U. Wandinger has formalized a scheme for ECARE using certain base aerosol classes.

A-PRO applied to Halifax scene

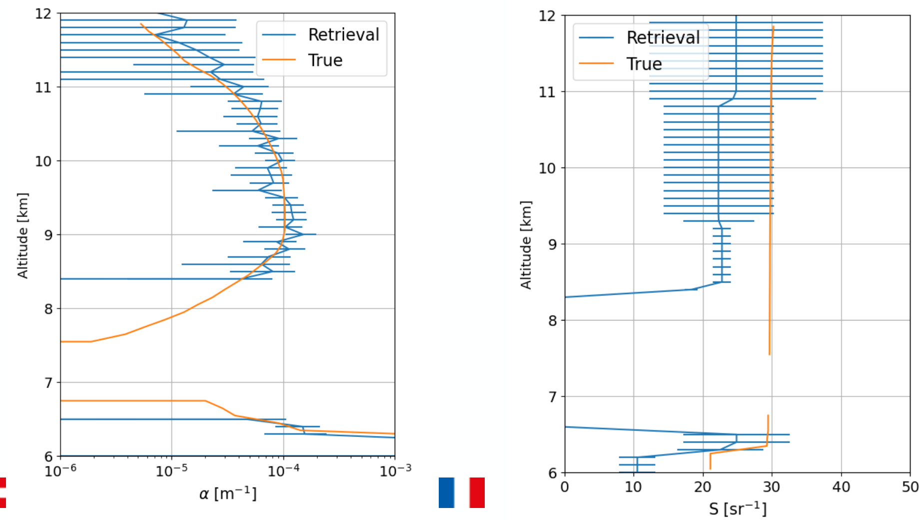




50 km “Medium” scale Aerosol



5 km scale: Cirrus



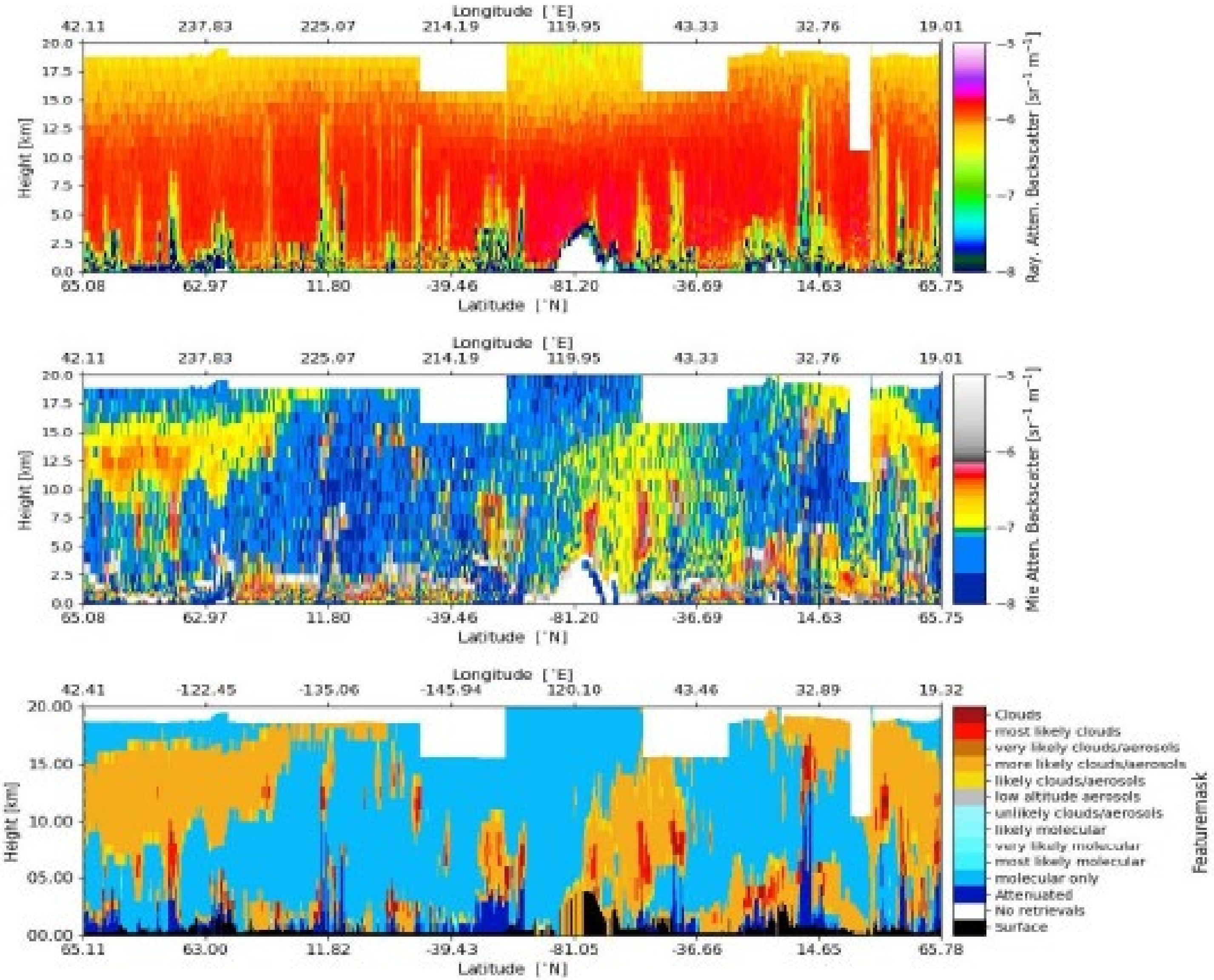
Testing using ALADIN observations

- AEL-FM and AEL-PRO have been adapted to ALADIN measurements !
  - Being implemented in the operational processor.
  - AEL-FM resembles A-FM more completely than AEL-PRO resembles A-PRO
    - E.g. Aeolus lacks depol. Measurements ➔ No aerosol type determination and simplified ice/water discrimination.

- Validation is ongoing using:
  - Terrestrial Lidar data
  - Comparison with CALIPSO.
  - Comparison with OMI AOT.

aeolus DISC DLR DoRIT ECMWF cnrs s[&]t ABB serco

AEL-FM Example: Sept 14, 2019



AEL-PRO Example

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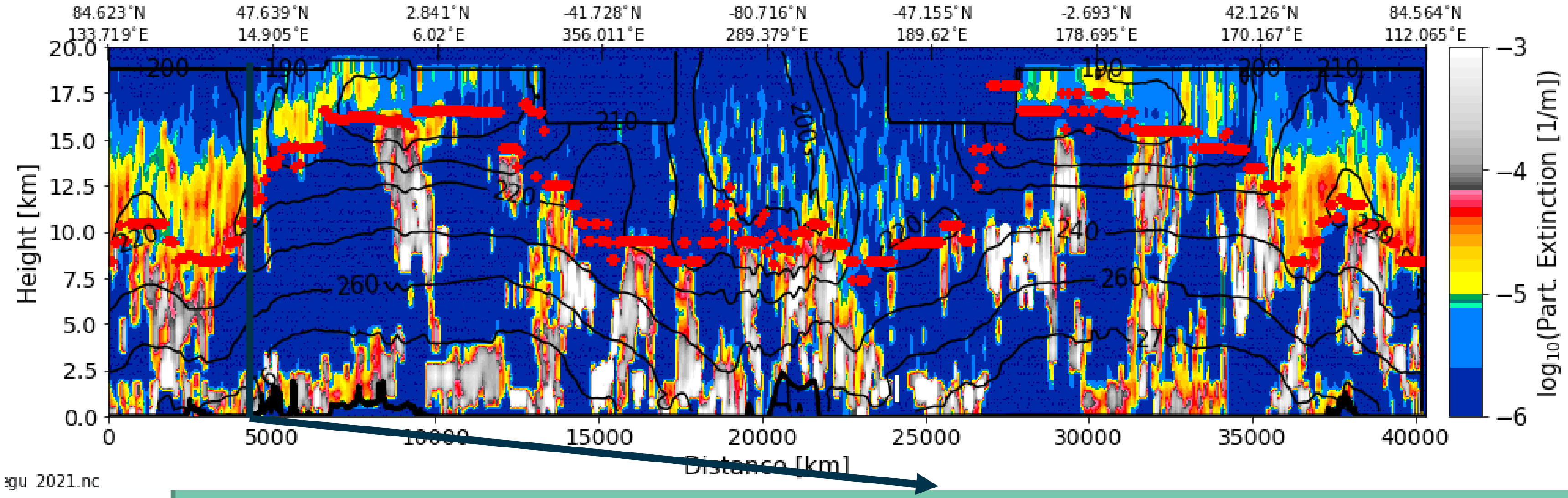

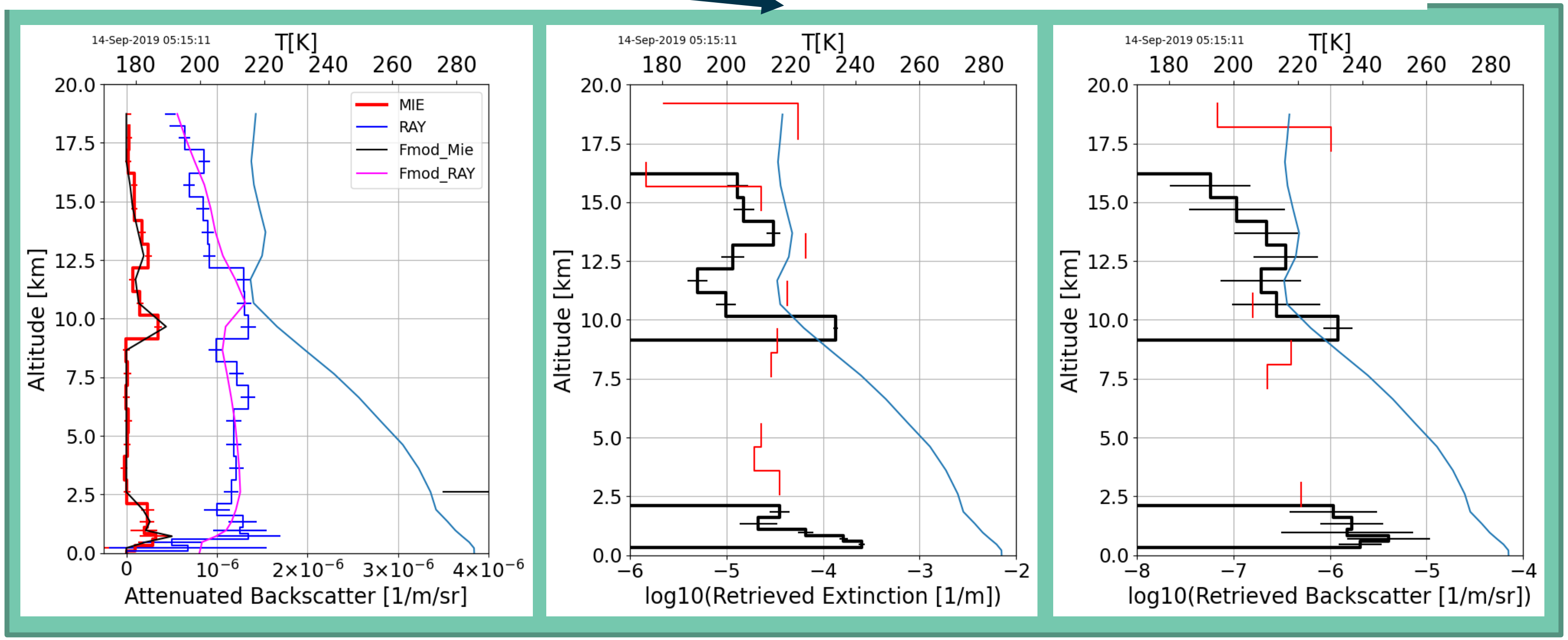

Example Comparison with CALIPSO

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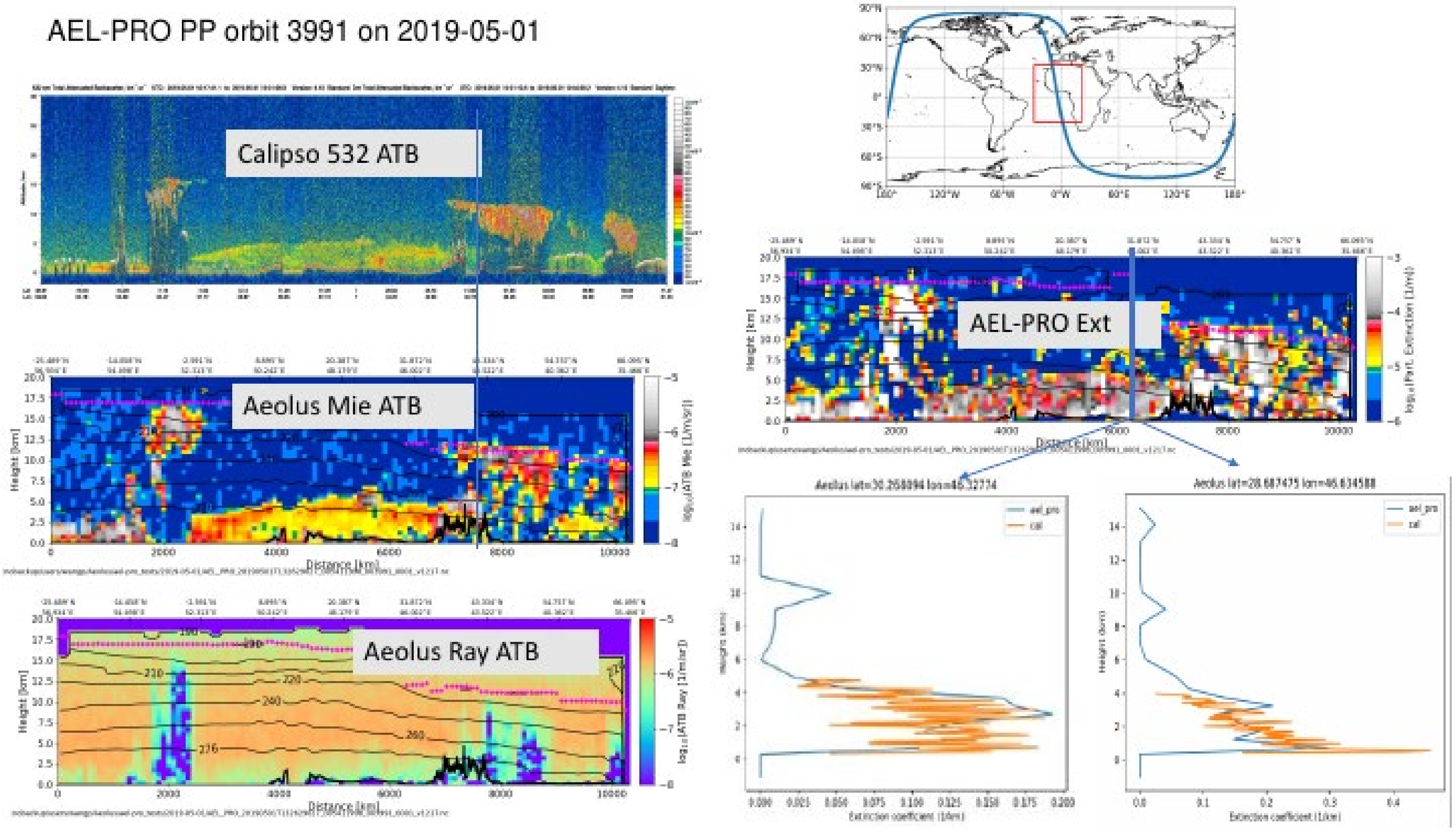
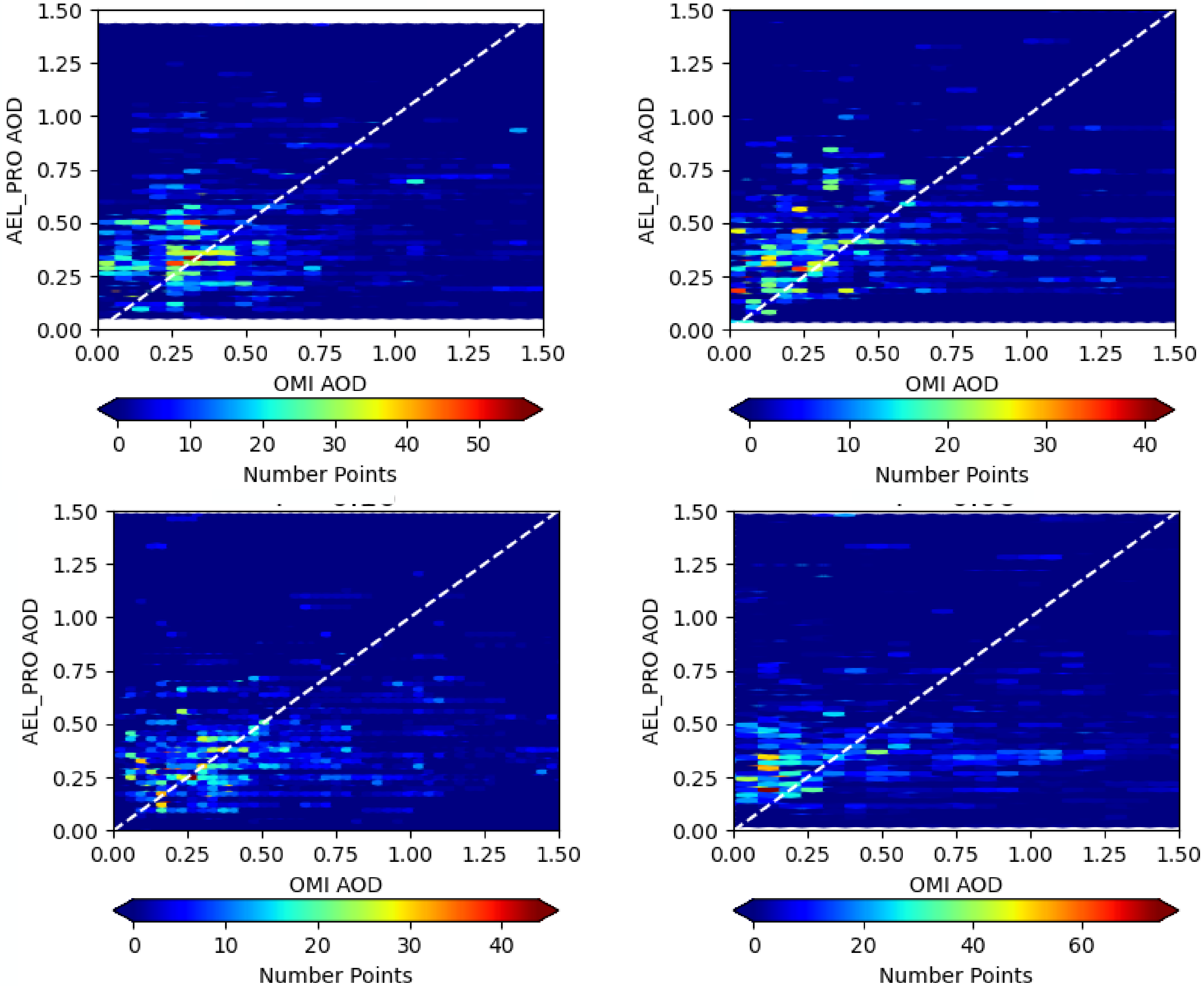


Fig. 4. CALIPSO and ALADIN ATBs and extinction retrieval within an orbit section within a few 10s of km and 3.5 hrs on May 01, 2019.

AEL-PRO AOT-vs-OMI AOT (Sept 2019)



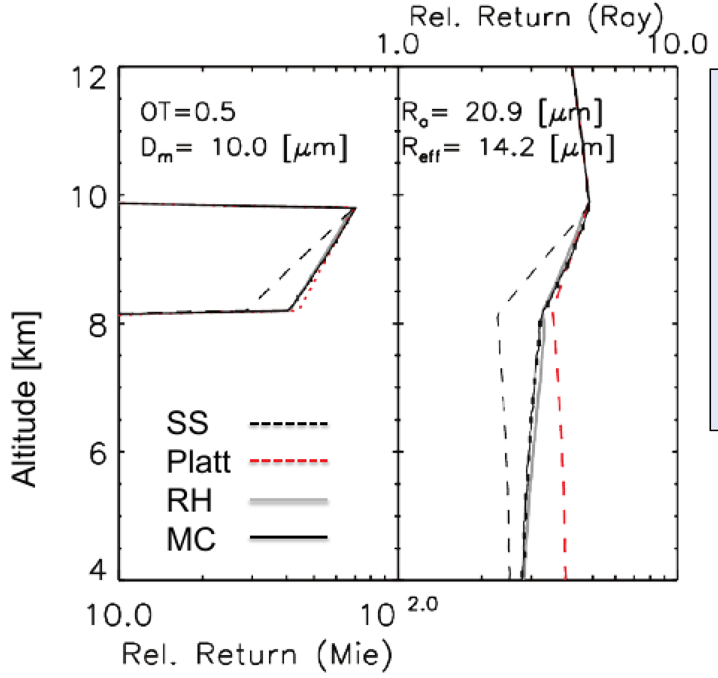
Summary

- A-FM and A-PRO have been developed over the past few years.
  - They have been tested primarily using synthetic data.

- AEL-FM and AEL-PRO have been developed based on A-FM and A-PRO
  - They are will become operational within the Aeolus OP this summer
  - Validation is ongoing using a variety of data streams

- Feedback between (A-PRO/A-FM ←→ AEL-FM/AEL-PRO) has been working in both directions.
  - Good example of synergy (what ECARE is all about) even before ECARE launch !

A simple approach for dealing with Multiple-Scattering



Within clouds: Platt's approach can work well but can not model the tails, but it is possible to extend Platt's approach !

Introduce a `f' factor which allows the signal to decay to single-scatter levels with range. f is the fraction of MS radiation that remains in the lidar fov.

Faster than Hogan's approach, but more ad-hoc and connection between "Decay" constants and particle sizes must be parameterized.

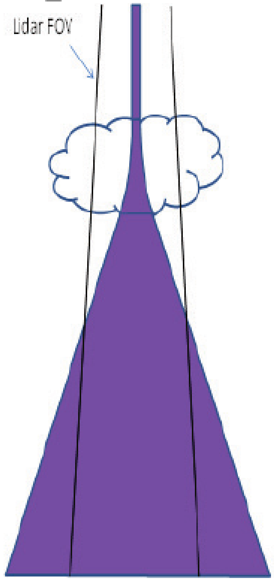
$$P(z)(z-z_{sat})^2 C_{lid}^{-1} = \frac{d\tau}{dz} e^{-2\tau(z)} \left[(1-f) + f e^{2\eta\tau(z)} \right]$$

Lidar fov

$$f = 1.0 - \exp\left[-\left(\frac{\rho_t^{\,2}(z-z_{Sat})^2}{\theta_e^{\,2}(z-z_l)^2 + \rho_l^{\,2}(z-z_{Sat})^2} \right) \right]$$

Effective MS divergence: Related to particle size

Effective MS emission level. Can be estimated from signal itself



- The Platt+Tails approach can be generalized to multiple layers
- Extra parameters are profile of eta and theta (related to particle size)
- The resulting Lidar equation can be inverted numerically !

Development of a OE based solver. That cane be applied at different hor. resolutions.

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

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

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

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

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

Effectively no constraint on extinction (other than being positive)