Performance Analysis of the ATLID Lidar: A Multi-Parameter Statistical Approach Using L1 Data

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Abstract

We propose a set of parameters, which would characterize the behavior of the ATLID lidar system on a day-to-day basis using the L1 data as an input. With the help of this set we will trace:

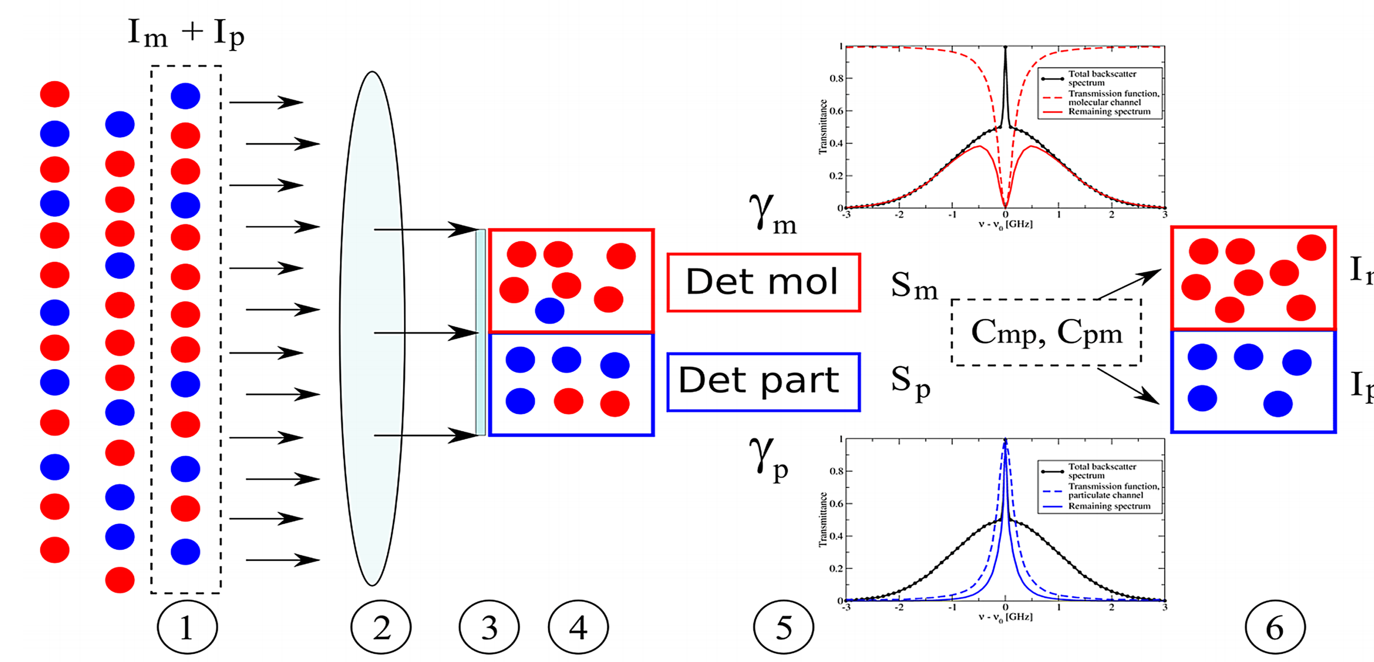
(a) the stability of the detection chain for ATLID channels (Rayleigh, Mie, and the cross-polarized one);
(b) the accuracy of cross-talk coefficients;
(c) the stability of day- and nighttime noise;
(d) the stability of the radiation detection for all atmospheric scenarios and over the whole globe using a clustering algorithm applied to the scattering ratio (SR) histograms.

We define 11 parameters: 3 related to surface reflection, 6 related to stratospheric day- and nighttime noise for 3 channels, and 2 related to the SR histogram analysis. We demonstrate the feasibility of the approach using CALIOP L1 data for polarized and cross-polarized attenuated backscatter (ATB) components in 2008−2015.

Calibrating space-borne instruments

- Calibration in the laboratory: high precision, repeatability, versatility. Not 100% consistent with the instrument after launch.
- Calibration in space using onboard sources and/or known external sources (stars, moon): typical for passive instruments.
- Calibration through collocation: ground-based stations, balloons, aircraft – compares the products (L2), involves L0→L1→L2 conversion, limited number of overlaps.
- Statistically based **quality control**: not equal to calibration, helps to identify issues in calibration and performance of the instrument, needs only a day-to-day flow of L1 data.

High Spectral Resolution Lidar (HSRL)

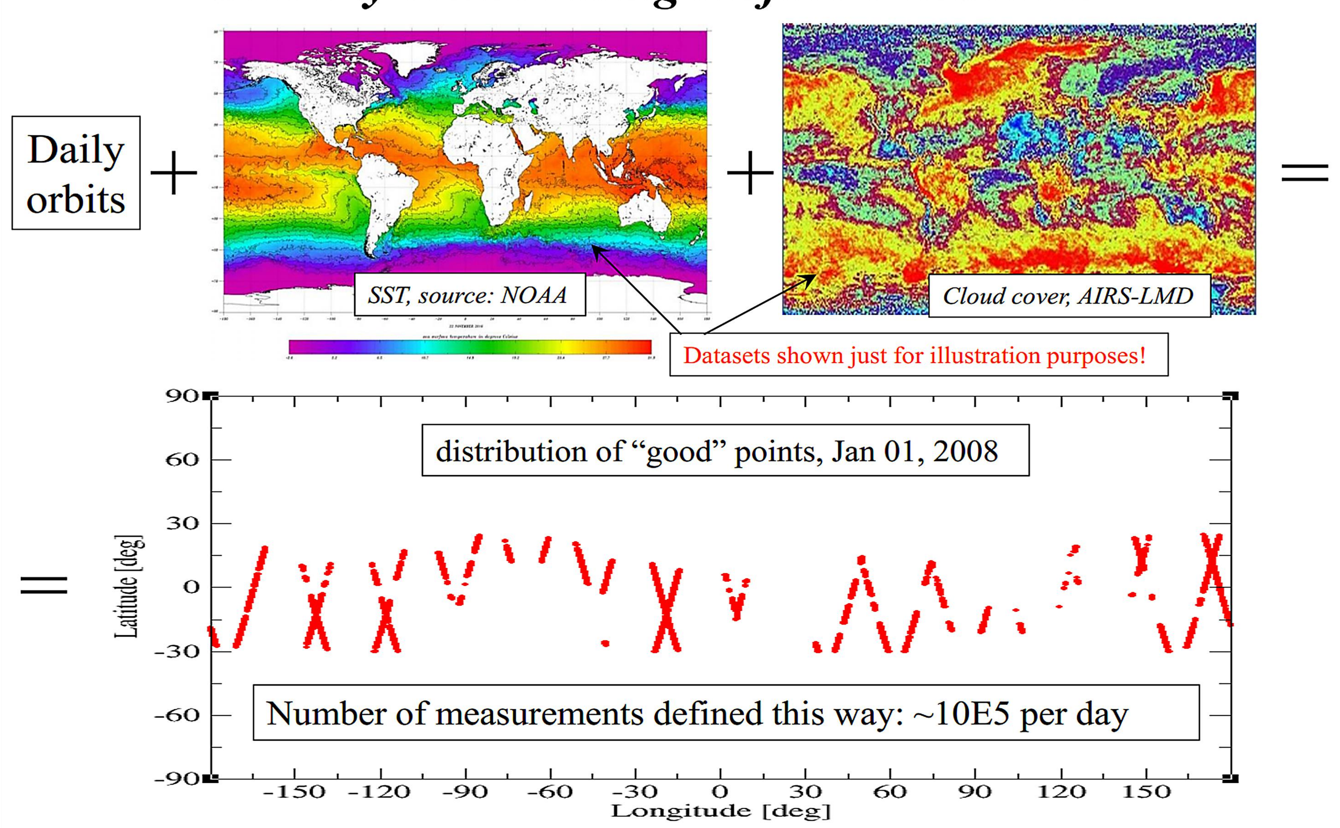


Schematic view of HSRL registering and treating the Rayleigh- (red) and Mie-scattered (blue) photons: (1) incoming flux, (2) telescope and optics, (3) HSRL splitting the components, (4) detectors, (5) transmission and spectra, (6) cross-talk free Rayleigh- and Mie-components

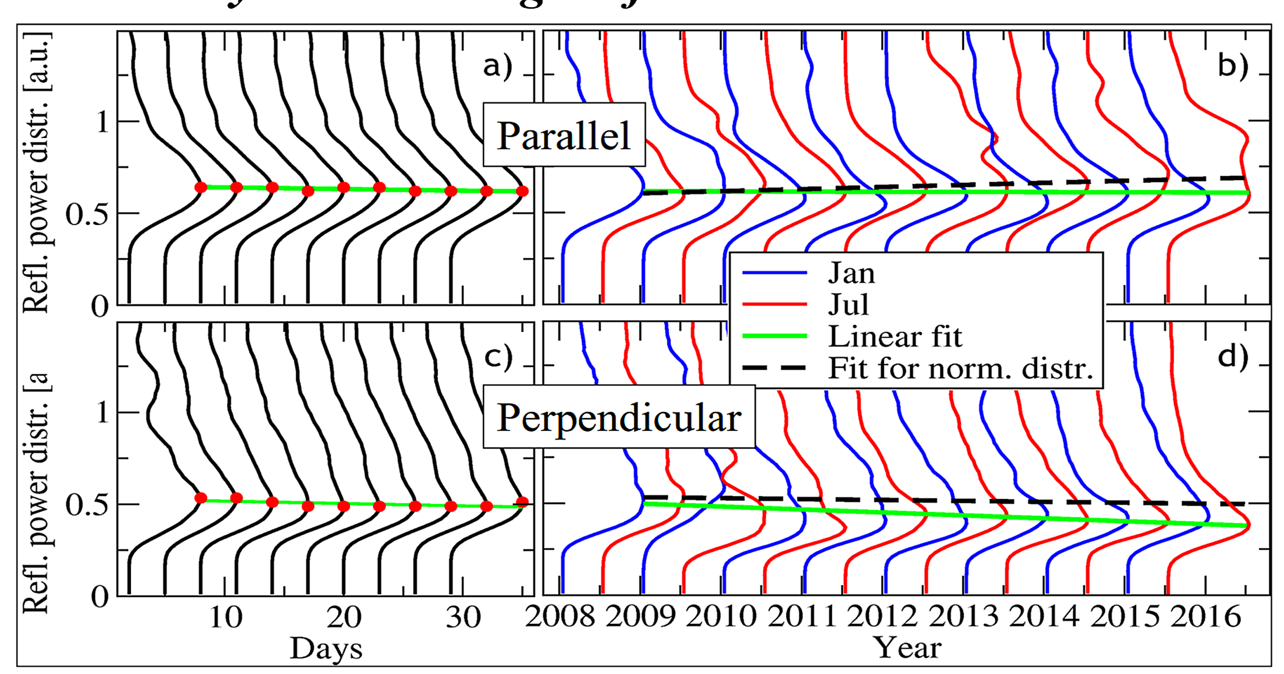
Formulation of the problem

- Elements of spaceborne lidar, related to calibration:
  - molecular channel
  - aerosol channel
  - cross-polarized channel
  - laser power measurement
  - sending and receiving optics (alignment, coatings, degradation)
  - data acquisition system (noise, electronic cross talk, etc)
- L0→L1 conversion requires knowledge of HSRL cross-talk coefficients (+ cross-talk for cross-polarized channel)
- How to detect drifts and offsets using only a flow of L1 data?
- Ideally, a set of parameters calculated on a day-to-day basis is needed: Δ_i < threshold$_i$ (i=1…N)

Stability control using surface backscatter

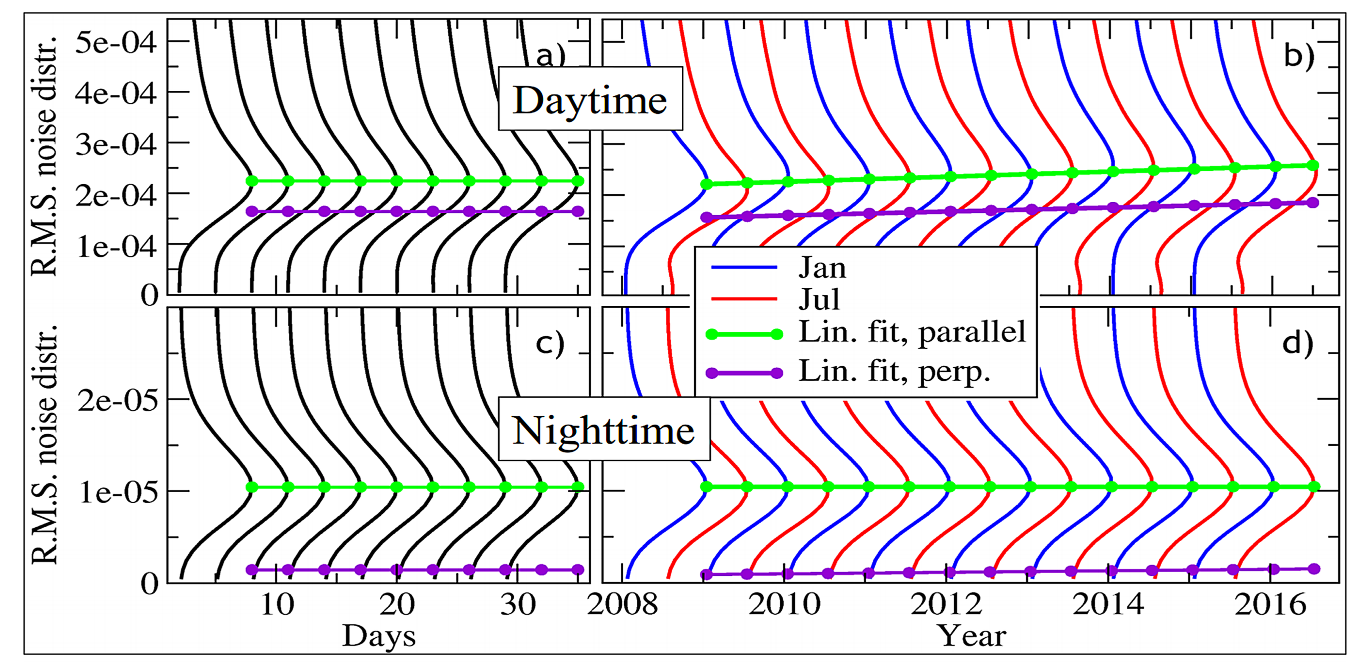


Stability control using surface backscatter: CALIOP



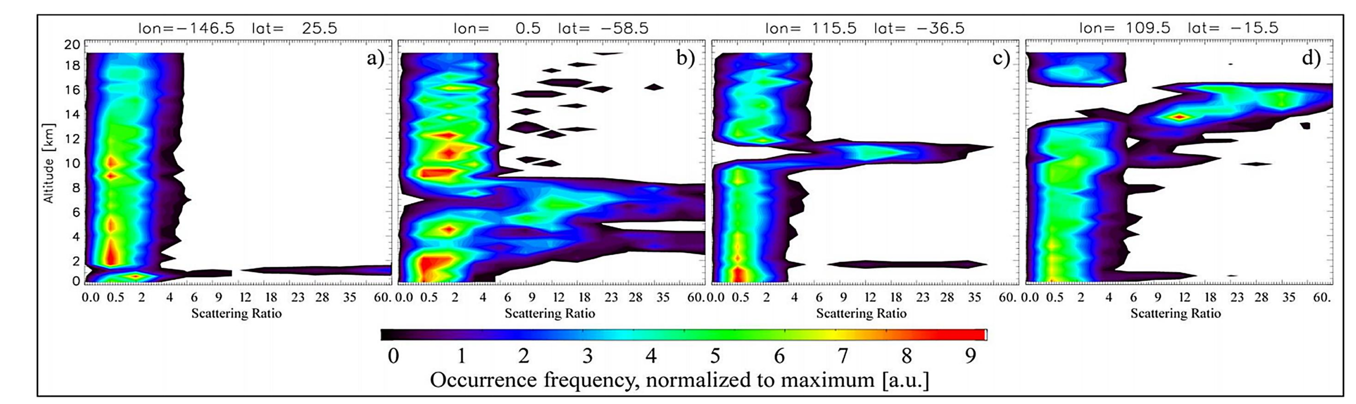
Stability control using surface reflection for CALIOP L1 data: (a) parallel component, 3-day statistics for January 2008; (b) same as (a), but for 2008–2015; (c, d) same as (a, b) but for perpendicular component. Dashed: linear fit for laser power-normalized ATB histograms.

Stratospheric noise analysis: CALIOP



Histograms of stratospheric (35–40 km) signals for parallel component and linear fit of parallel (green line) and perpendicular (violet line) histogram maxima for: (a,b) daytime and (c,d) nighttime; (a, c) are zoomed versions of the first month of (b, d), respectively

Scatterring ratio histograms: typical scenes

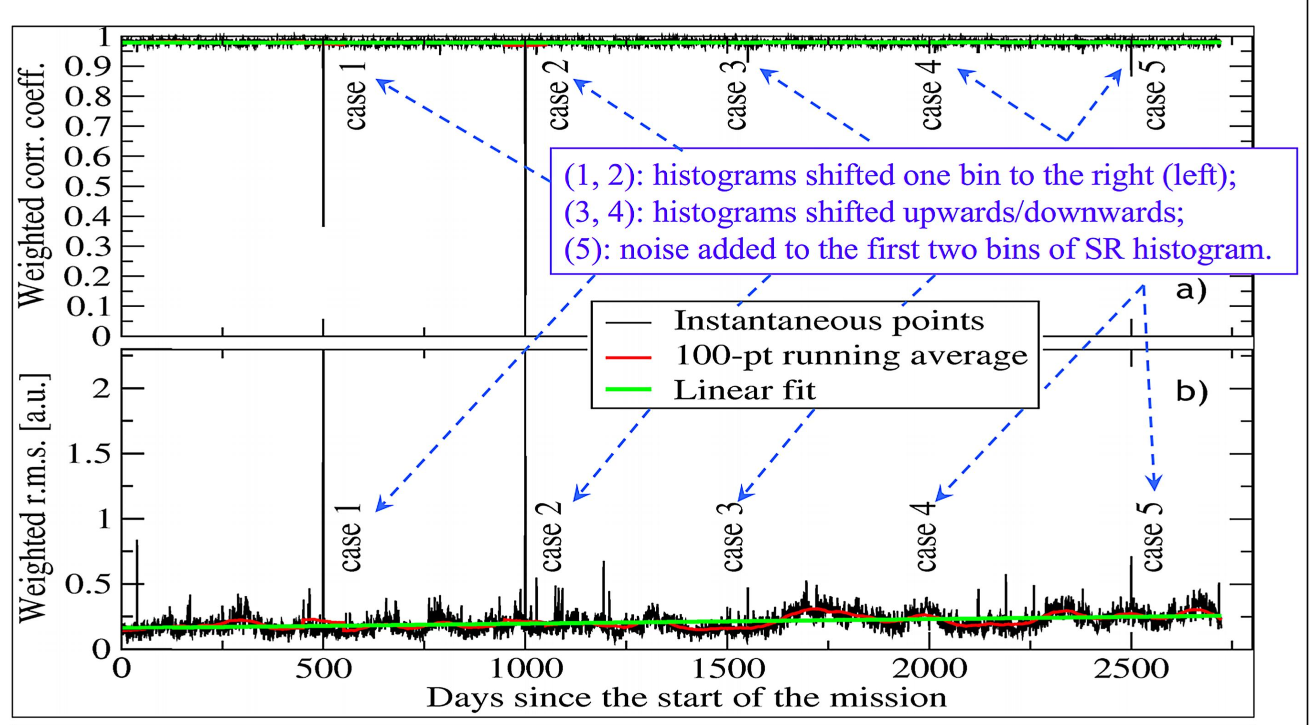


Examples of height-intensity SR histograms calculated for CALIOP: a) clear sky; b) multi-layer middle level cloud; c) high semi-transparent cloud; d) thick high cloud.

Approach already used by Marchand et al. [2008] for CloudSat and Chepfer et al., [2010] for CALIOP. Further development – **clustering** the same-type SR histograms:

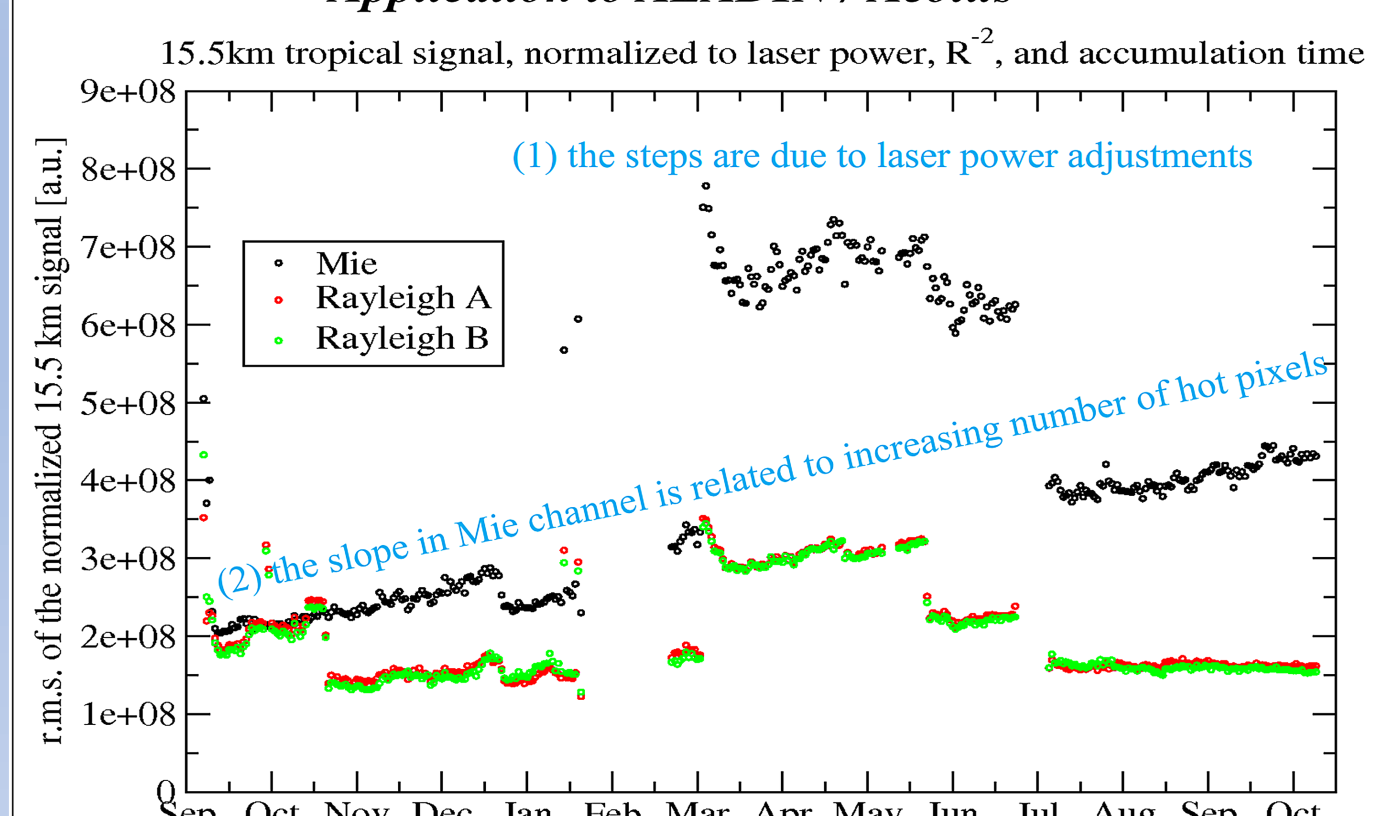
- "Clustering … groups a set of objects in such a way that objects in the same group are more similar to each other than to those in other groups" [Everitt, 1993].
- Clustered histograms have good signal-to-noise ratio due to large statistics and they do not change in time rapidly. If new or rare phenomenon appears, it will be detected as such and it won't spoil the analysis.

Quality control using SR clustering: 8 years of CALIOP

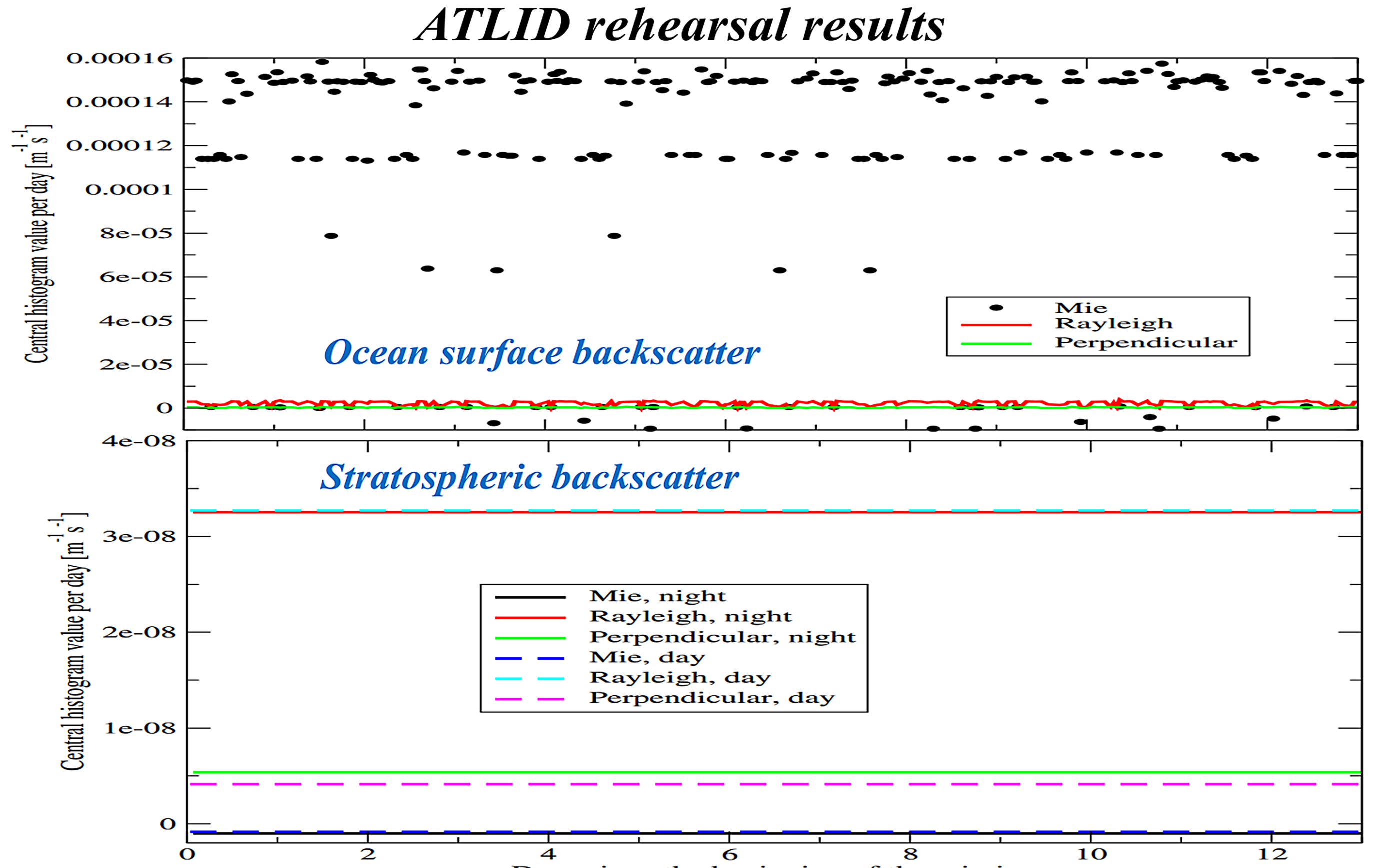


Daily quality criteria: (a) weighted correlation coefficient; (b) weighted r.m.s. of the difference. In 5 test cases the histograms were perturbed to simulate calibration issues.

Application to ALADIN / Aeolus



ATLID rehearsal results



Summary

- We propose a set of 11 quality control parameters:

N	Channel/data	Description
1	Mol.	Center values of histograms of radiance reflected from the ocean with T_{surf} = 300±1 K.
2	Part.	
3	Perp.	
4	Mol. day	Center values of histograms of daytime and nighttime stratospheric molecular signal (~35km) or noise (higher altitudes).
5	Part. day	
6	Perp. day	
7	Mol. night	
8	Part. night	
9	Perp. night	
10	K_{corr}, SR histo	Weighted average of the correlation coefficient or deviation for the clustered scattering ratio histograms w.r.t. the reference or the first day
11	R.M.S., SR histo	

- We demonstrate the feasibility using 8 years of CALIOP data.
- Application to Aeolus data revealed laser power adjustments and increasing number of hot pixels.
- ATLID rehearsal shows the readiness to real data flow.