Features of Electric Field Measurements during Thunderstorms Using Polarization LIDAR System.

Phases for development of a method for E-field measurements

Under cloud E-field

1. Using *Linear polarized* laser beams and analyzing the *depolarization* of backscattered signals from *Topographic Targets.*
2. Using *Linear polarized* laser beams and analyzing the *depolarization* of backscattered signals from the *Cloud Bottom.*
3. Using *Circular polarized* laser beams and analyzing the *polarization ellipticity* of backscattered signals.

Compare the results with E-field sensor's data.

Intracloud E-Field

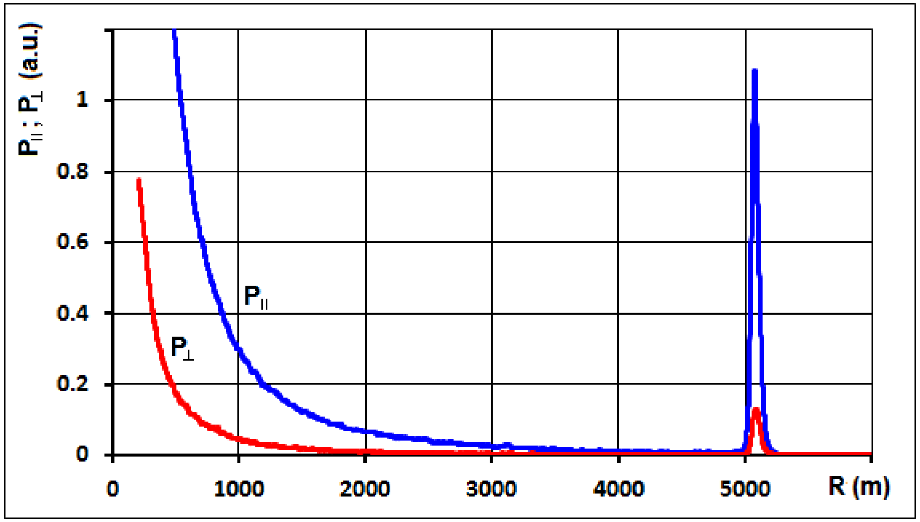
4. Using *Linear polarized* laser beams and analyzing the *depolarization* of *Intracloud* backscattered signals.

5. Measurements of the water Raman backscatter signal's *depolarization* from the *Atmosphere and Clouds* in the range of the spectral band of water (0.630um-0.650um).

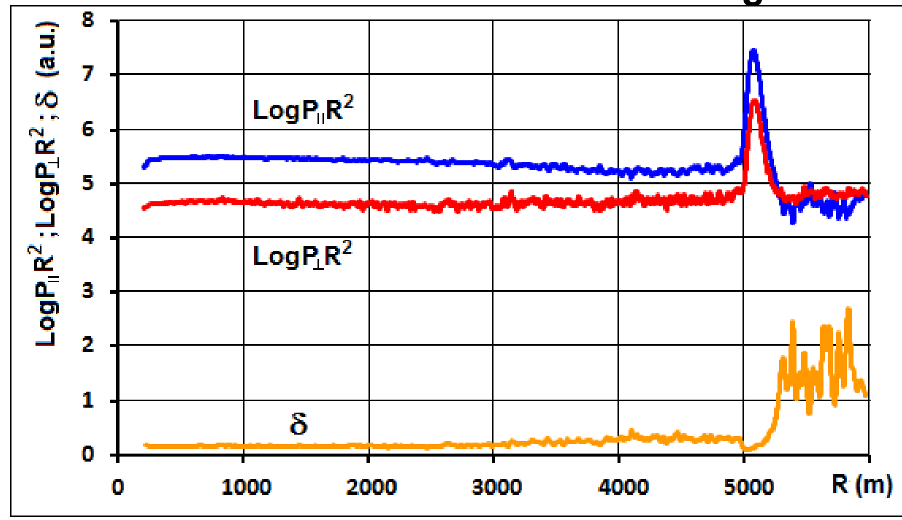
The YerPhI Polarization LIDAR System

Backscattered Profiles (Atmosphere With Cloud)

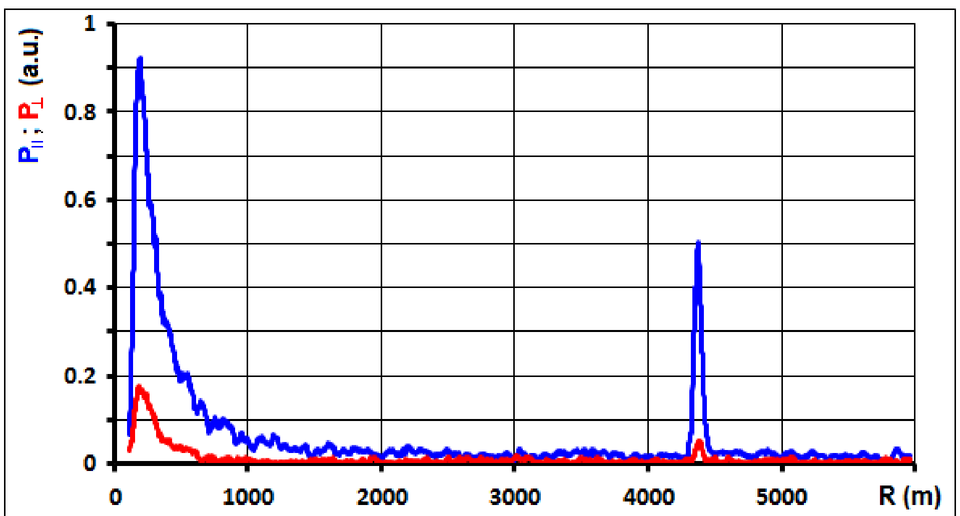
Zenith Angle = 60°



Polarization separated backscatter profiles.



Range normalized backscatter and depolarization ratio profiles.



Polarization separated profiles with 1sec interval.

$$P(\lambda,R)=\frac{KP_L}{R^2}\beta(\lambda,R)exp(-2\alpha R)$$

K - *System efficiency*

P_L - *Laser power*

$\beta(\lambda, R)$ - *Backscatter coefficient*

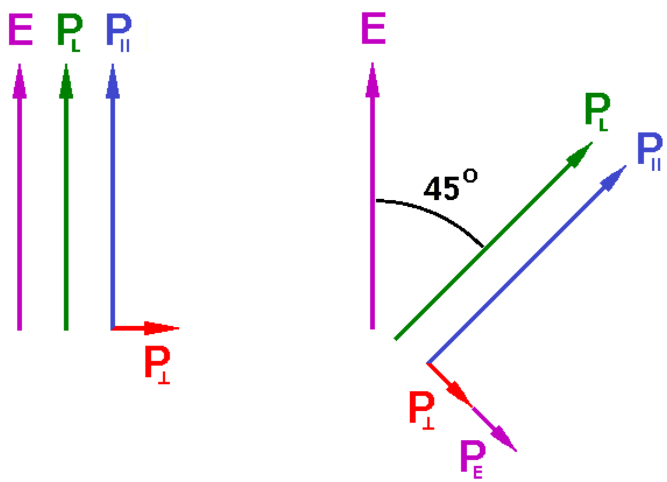
$exp(-2\alpha R)$ - *Atmospheric attenuation*

Measured Data by LIDAR

$$\frac{P(\lambda,R)}{P_L\,K}\cdot R^2=\beta(\lambda,R)\cdot exp(-2\alpha R)$$

$$\delta(R)=\frac{P_{\perp}(\lambda,R)}{P_{\parallel}(\lambda,R)}$$ - *Depolarization ratio*

Kerr Effect For Electric Field Observations



$\mathbf{E}$ – Electric field

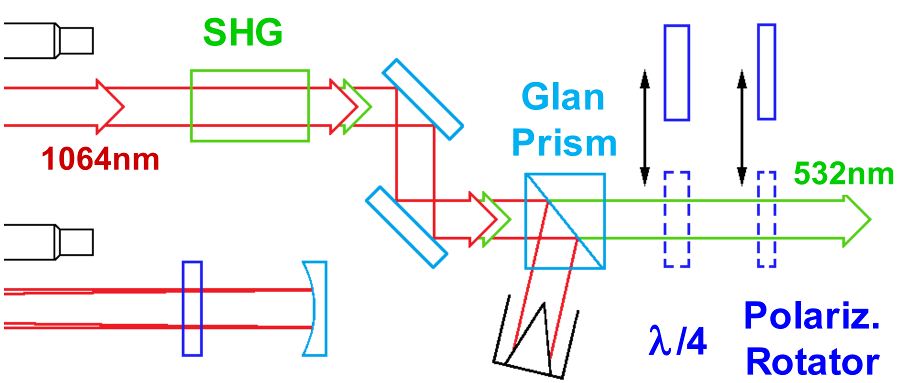
$\mathbf{P_L}$ – Laser Power

Backscattered polarization components

$\mathbf{P_{||}}$ – Parallel to Laser beam

$\mathbf{P_{\perp}}$ – Depolarized by the Atmosphere

$\mathbf{P_E}$ – Rotated by the Electric field



Laser Beam Polarization Capabilities		
	1064 nm	532 nm
1	none	vertical
2	none	45°
3	none	circular
4	horizontal	vertical
5	horizontal	horizontal
6	vertical	circular
7	circular	horizontal
8	45°	45°

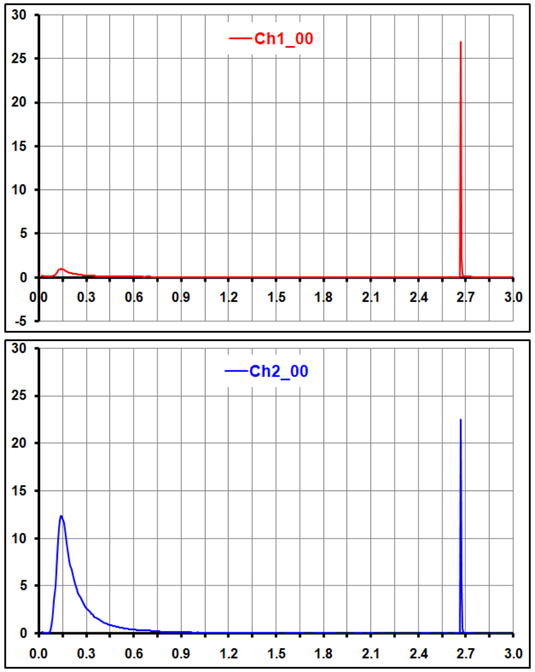
Some Estimations

$$\varphi = 2\pi (n_o - n_e) R / \lambda = 2\pi B R E^2$$

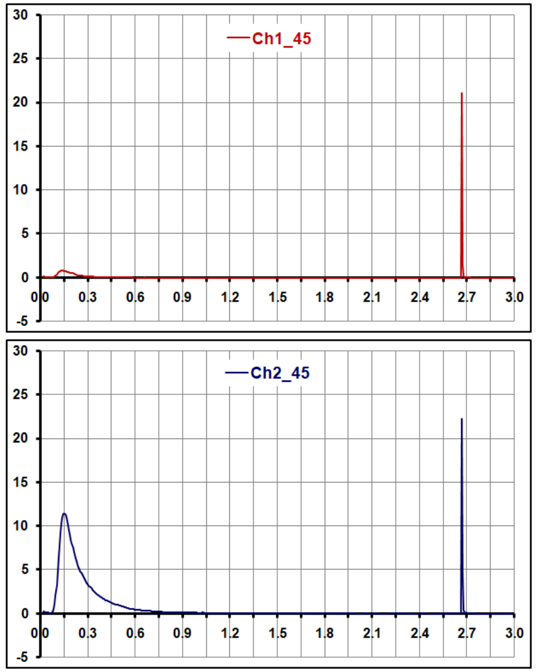
$B_{air} = 2.3\ 10^{-16}$ cm/V²

For E = 1000 V/cm, R = 5 Km => $\varphi = 1.45\ 10^{-3}$

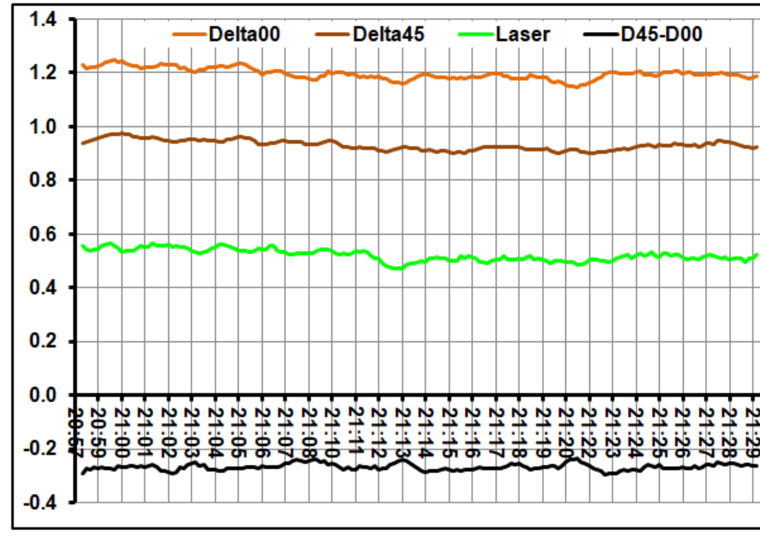
Topographic Target for Under-Cloud E-Field Observations 20.05.2019



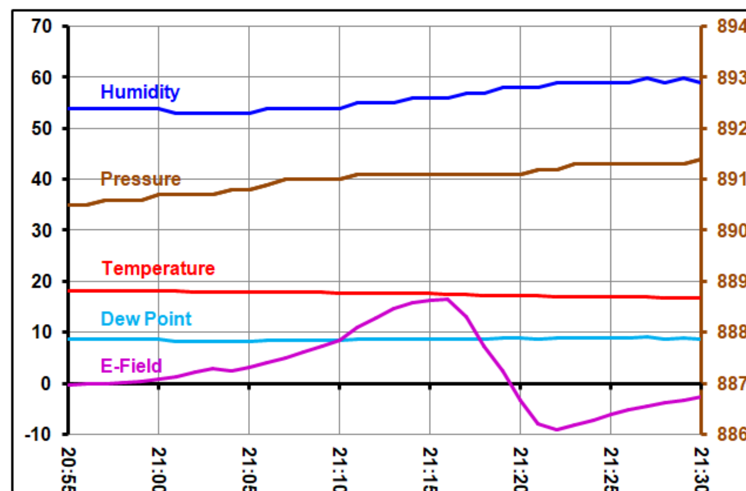
LIDAR return for 0deg (vertical) Polarization.



LIDAR return for 45deg Polarization.



Depolarization Ratios for 0deg and 45deg laser polarizations and their difference for the distance of 2664m.



Advantage:

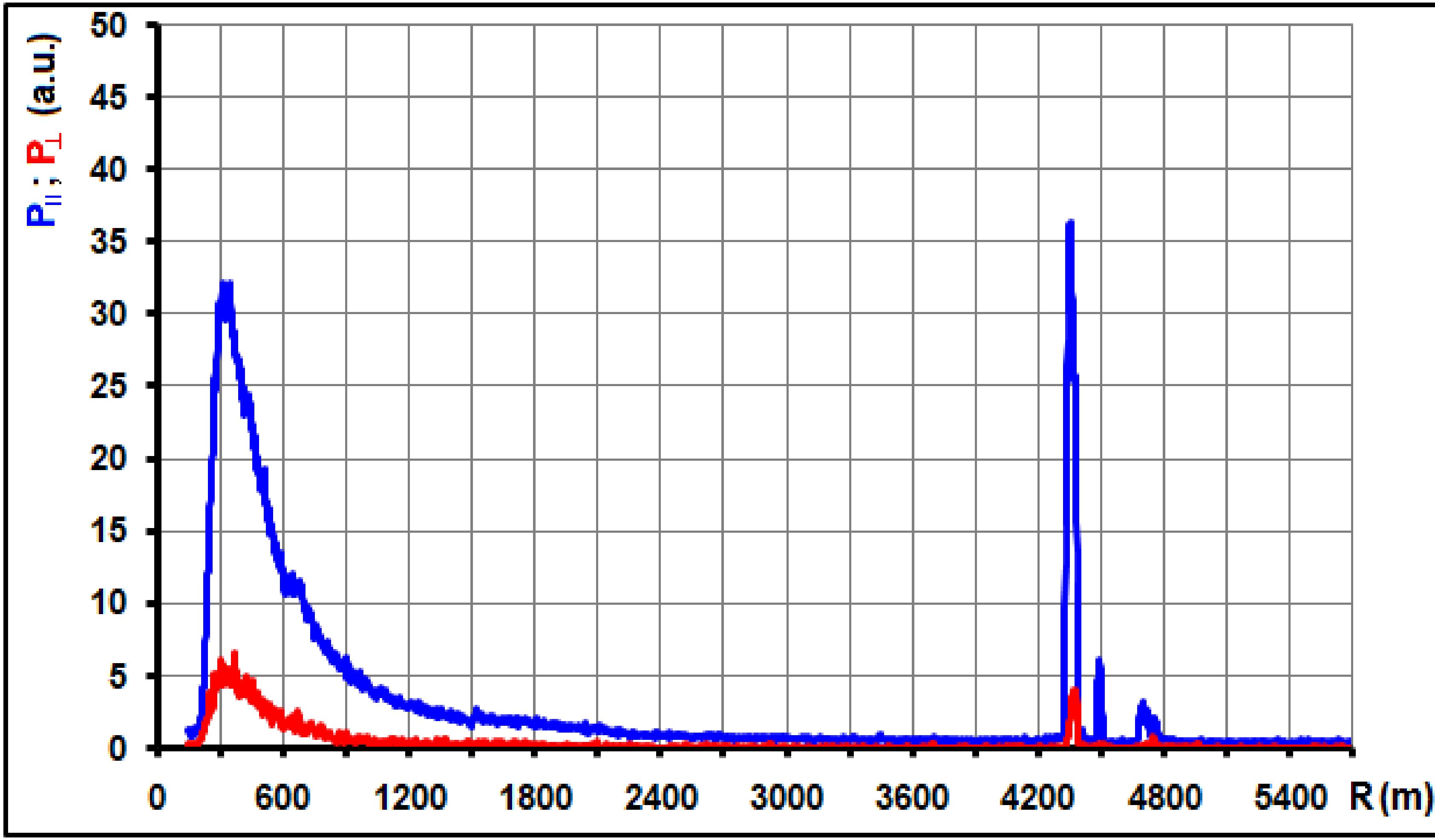
Reflection from any Topographic target is several orders of magnitude more than from Atmosphere or Cloud.

Disadvantage:

The surface of target depolarize the beam.

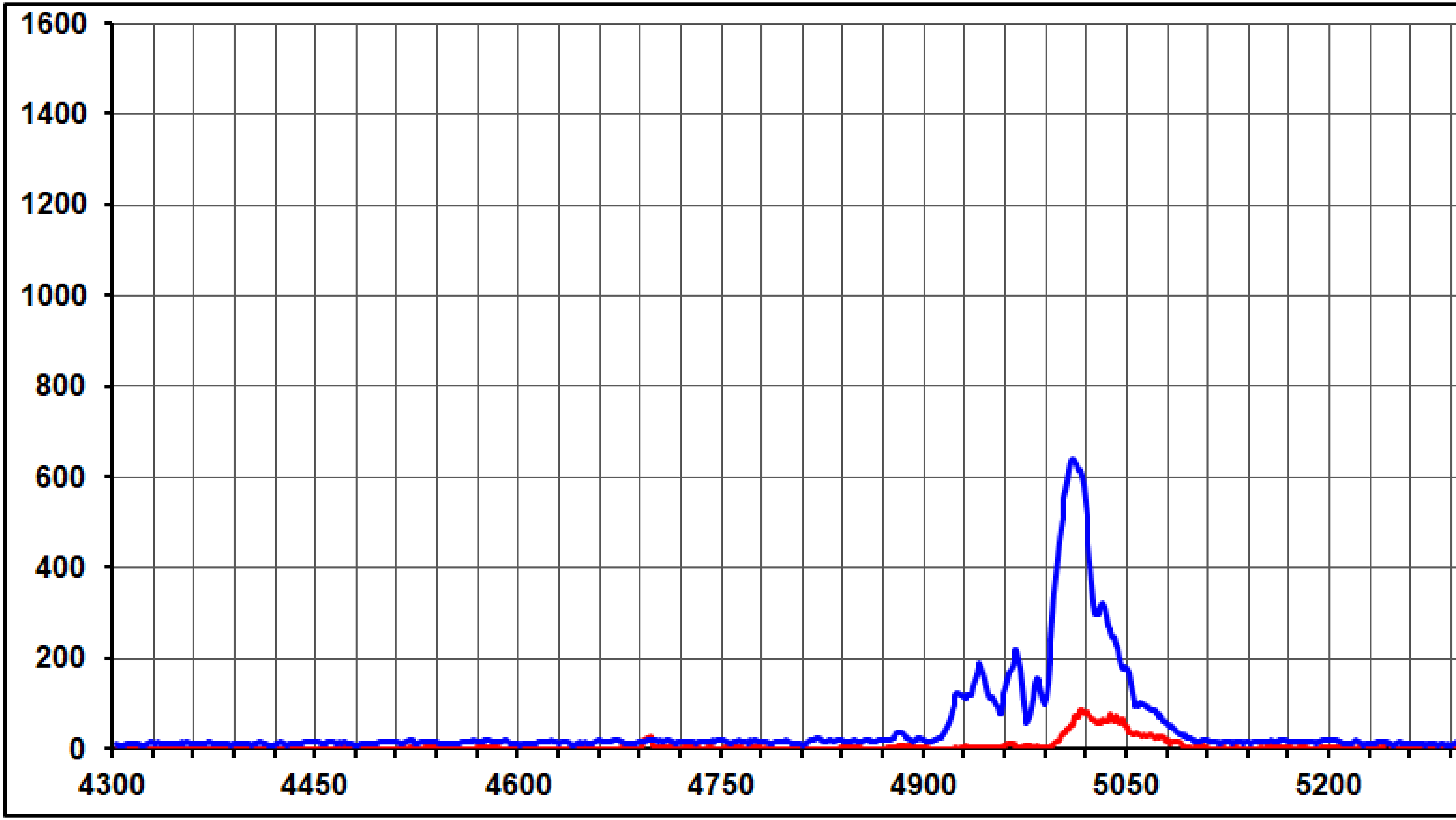
LIDAR Return Profiles (Atmosphere With Cloud) 06.06.2019_21:03-21:20

Zenith Angle = 45°



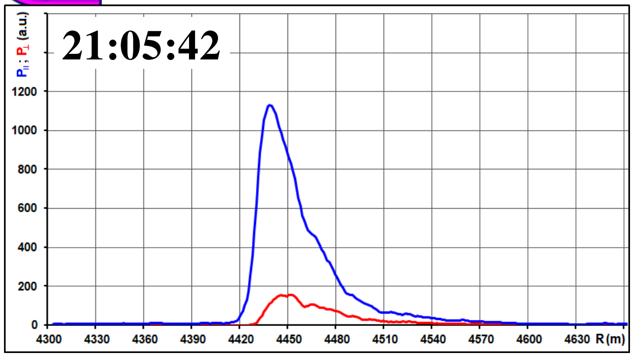
Polarization separated profiles with 5 sec interval (60 of 208).

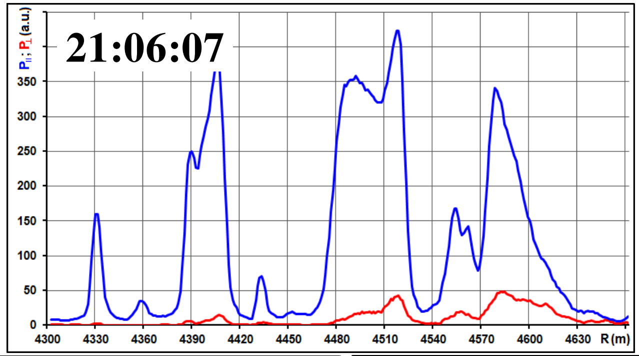
LIDAR Return Profiles From Cloud 06.06.2019_21:03-21:20

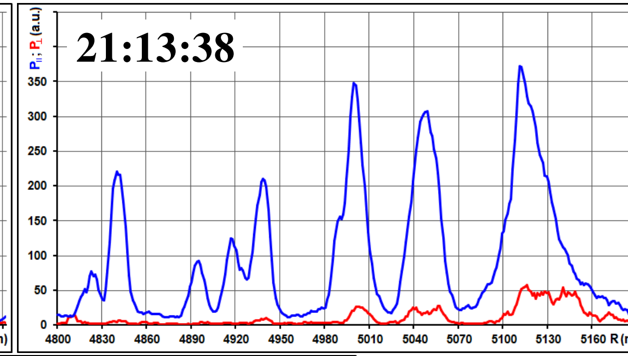


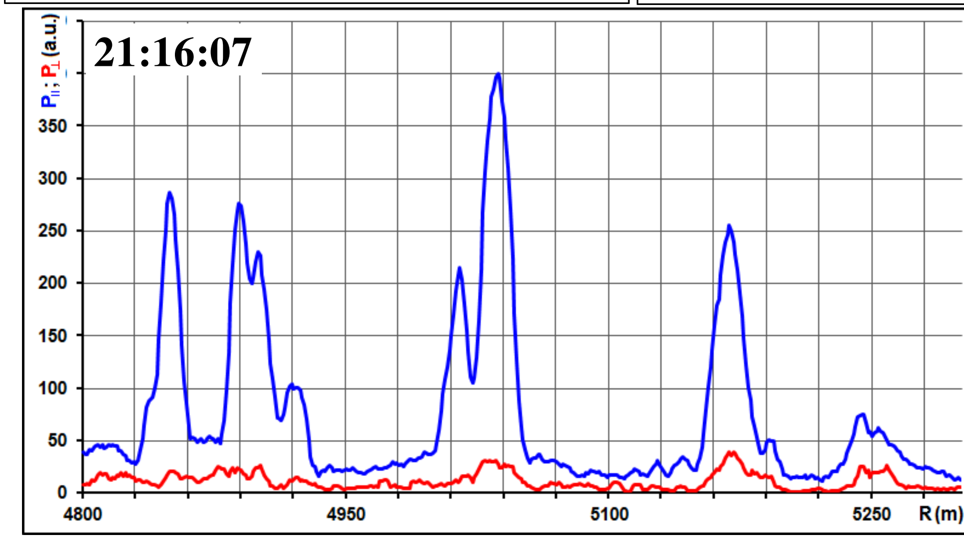
Range normalized Lidar return profiles with 5 sec interval (170 of 208).

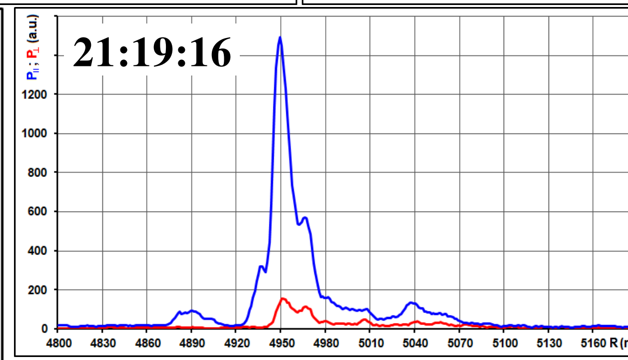
Fragments of Range Normalized Lidar Return Profiles From Cloud 06.06.2019



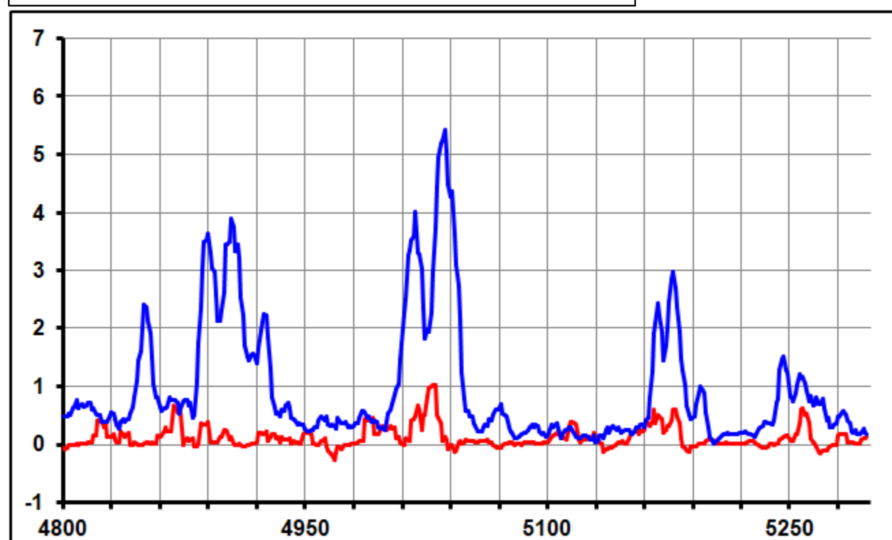








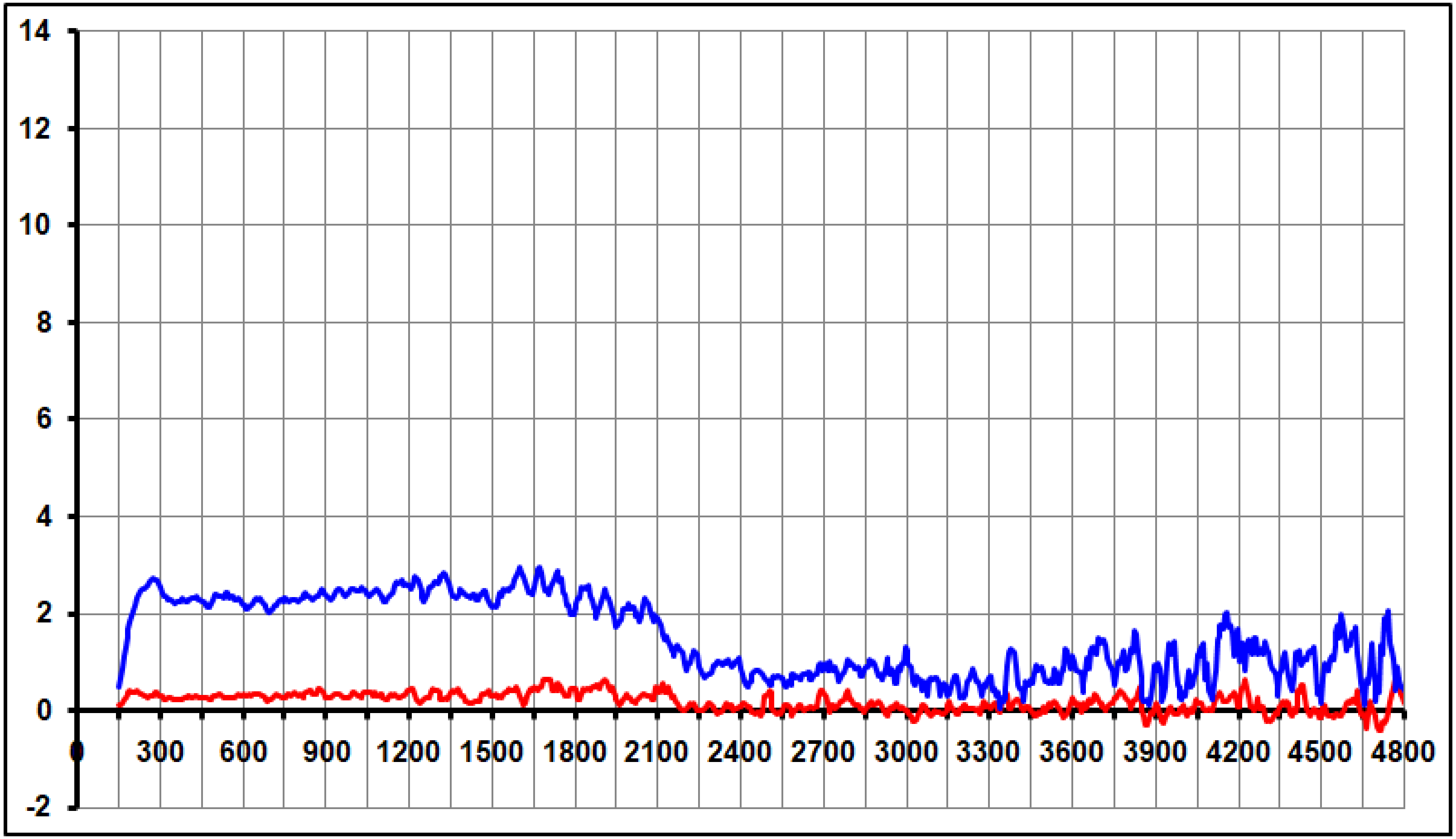
Fragments of range normalized Lidar return profiles - averaged by 10.



21:16:07 - Range normalized Lidar return profiles with 0.1 sec interval.

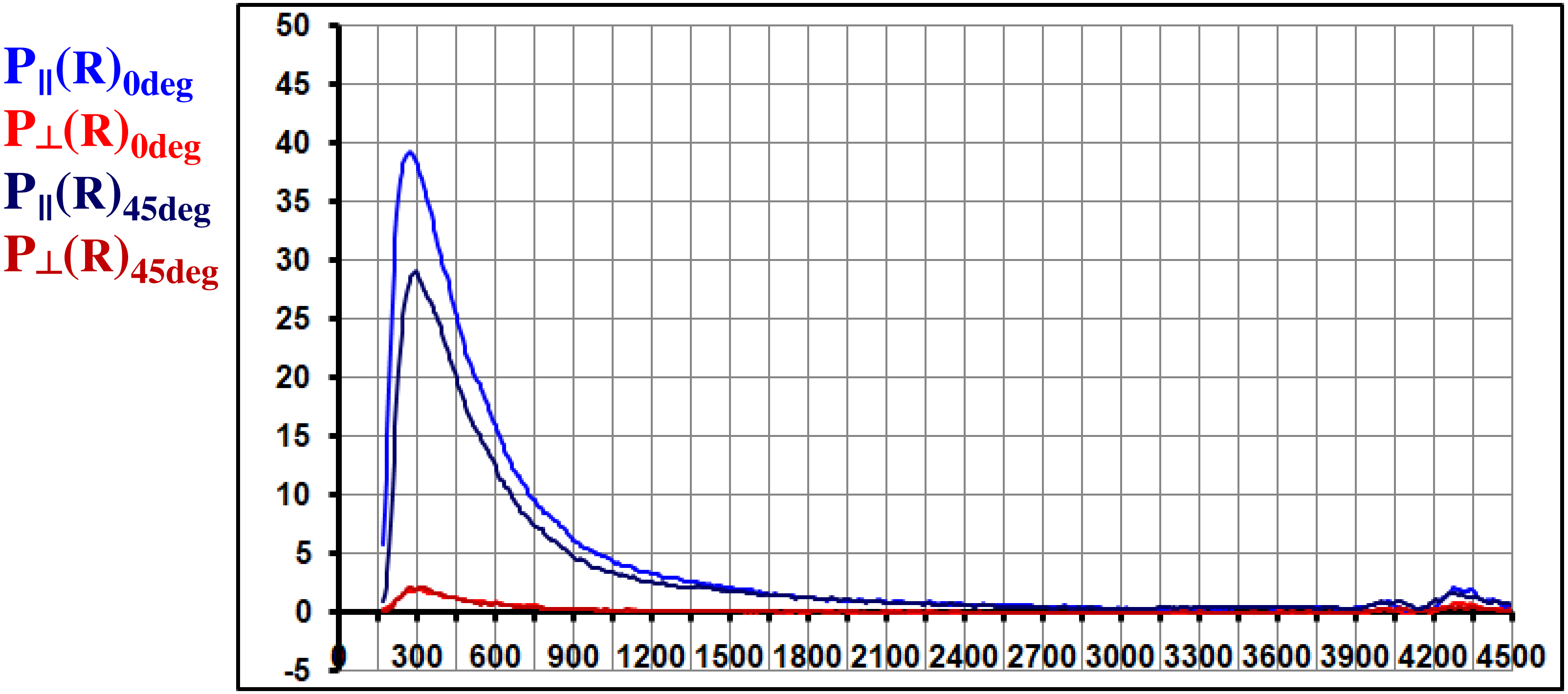
Range Normalized Lidar Return Profiles 10.06.2019

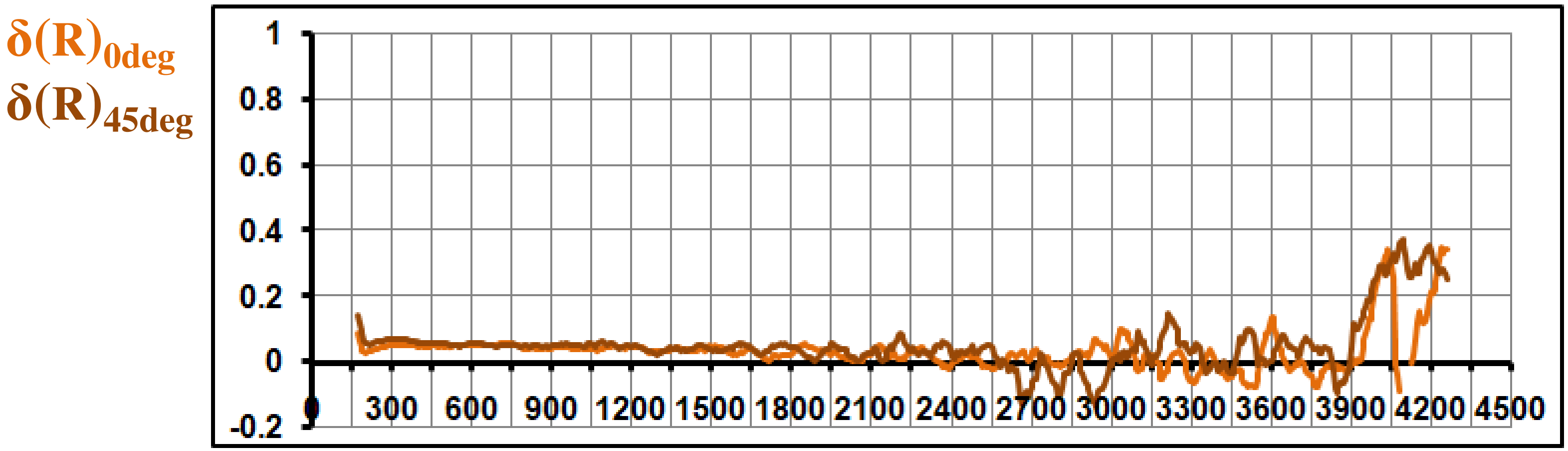
21:21 - 21:30



Range normalized Lidar return 80 profiles from atmosphere and cloud with 5 sec interval. Last 40 profiles are during rain.

Lidar return and corresponding Depolarization Ratio Profiles





Depolarization Ratio δ(R) is one of the best tools for LIDAR monitoring.