Multi-wavelength polarization Lidar characterization of mineral dust at Dunhuang (PRC)

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Outline

- Project background
- Lidar «AMPLE» design
- Lidar system calibration and test
- Some results from the field measurements

Background

Beijing

Background:

Etna

Background:

CHINA-ITALY LASER REMOTE SENSING TECHNOLOGY RESEARCH CENTER

CNISM - Beijing Research Institute for Telemetry

consorzio nazionale interuniversitario per le scienze fisiche della materia

Background:

1. **Joint research project between the National Consortium of Italian Universities for the Physical Science of the Matter (CNISM) and the Beijing Research Institute for Telemetry - BRIT**

AMPLE -

Aerosol Multiwavelength Polarization Lidar Experiment

2. **Cooperation between CNISM and INGV-Catania, INAF-Catania**

AMPLE design:

1. **High dynamic signal range** – for high dense aerosol measurement
2. **Depolarization measurements** – for distinguishing the particle shape
3. **Multiwavelength channel** – for particle dimension evaluation
4. **Raman capability** – for quantity measurement
5. **Scanning capability** – for 3D mapping
6. **Compact** - for mobile measurements

AMPLE specification:

1. **Laser source**:

- Diode pumped Nd:YAG (Bright Solutions)
- Fundamental , 2nd and 3th harmonics
- Pulse rep. rate: 1000 Hz
- Output power:

  0.6 W @ 355nm; 1.5 W @ 532nm; 1 W @ 1064nm
- Pulse width ~ 1 ns
- Linear polarization > 100:1

AMPLE specification:

2. **Receiver system**:

- Elastic channels @ 355nm, 532nm and 1064nm
- Raman channels @ 386nm (N_2), 407nm (water vapor) and 607nm (N_2)
- Depolarization @ 355nm and 532nm

Total photon counting

- Telescope: 20 cm Cassegrain
- Field of View: 1 mrad

AMPLE specification:

3. **Scanning system**:

   - Elevation range: from -10° to 100° ;
   - Azimuth range: from -110° to 110° ;
   - Scanning speed: max 20°/s ;
   - Scanning angle error: < 0.2°

4. **Weight** < 100 kg

5. **Power consumption** < 700 W

AMPLE specification:

4. **Output**:

- Aerosol backscattering coefficient

  @ 355nm, 532nm and 1064nm (day and night);

- Aerosol extinction coefficient

  @ 355nm, 532nm (night);

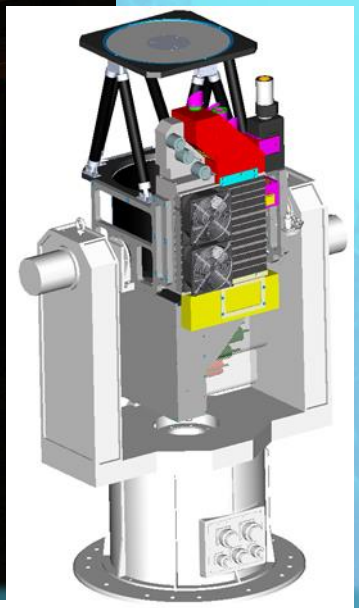
- Aerosol depolarization ratio

  @ 355nm and 532nm (day and night);

- Water vapor mixing ratio (night);

- Spatial resolution: 15m (raw), 60-180m (final);

- Temporal resolution: 2s (raw), 1-30 min (final)




AMPLE-1

Lidar system calibration and test

- Overlap function
- Multiwavelength channel calibration
- Depolarization calibration
- Water vapor Mixing Ratio test
- Comparison with Sun-photometer

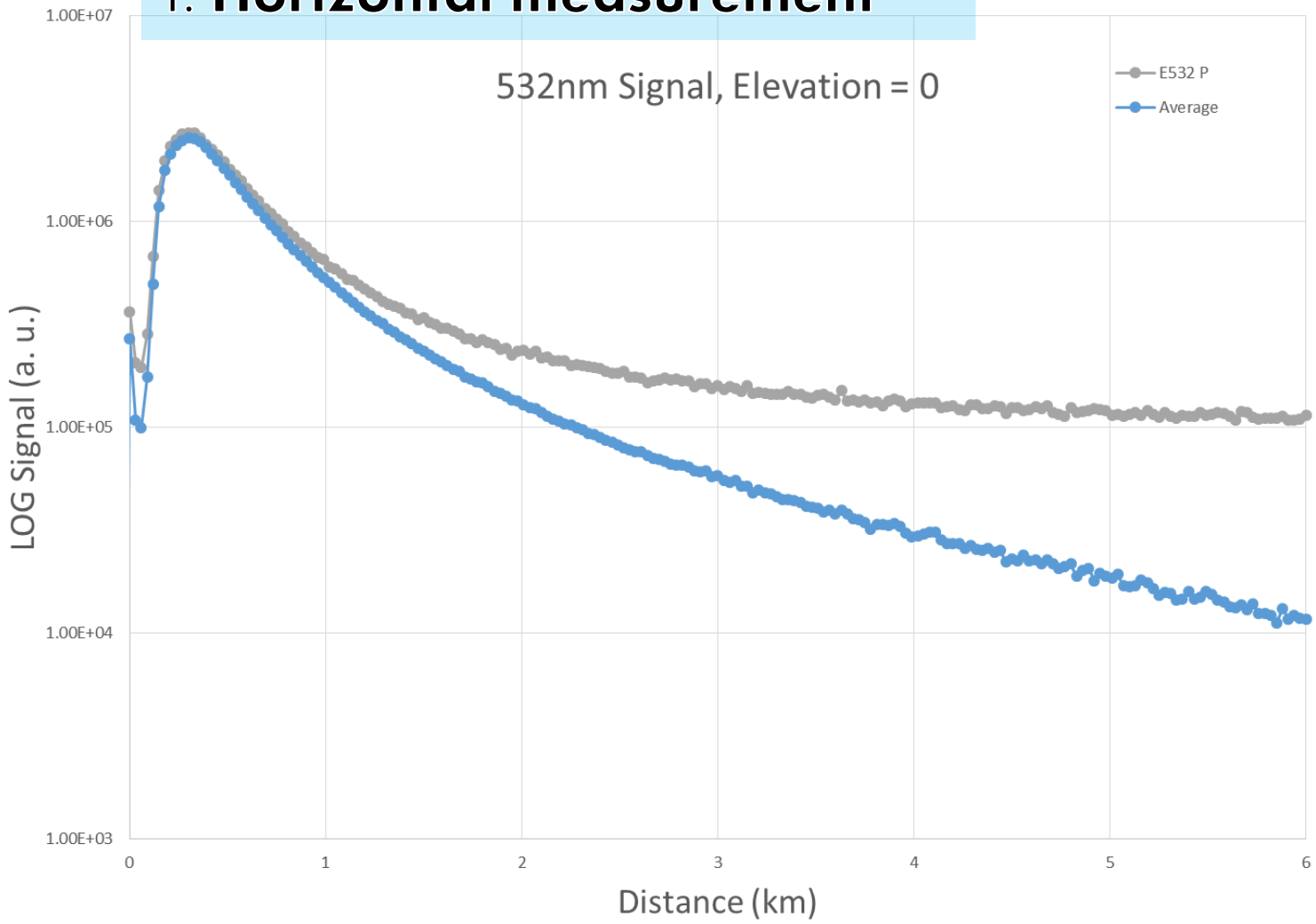
Lidar system calibration and test

- Overlap function
  - Horizontal measurement
  - Iterative from backscatter measurements both Raman and Elastic

Calibration and test

Overlap function determination

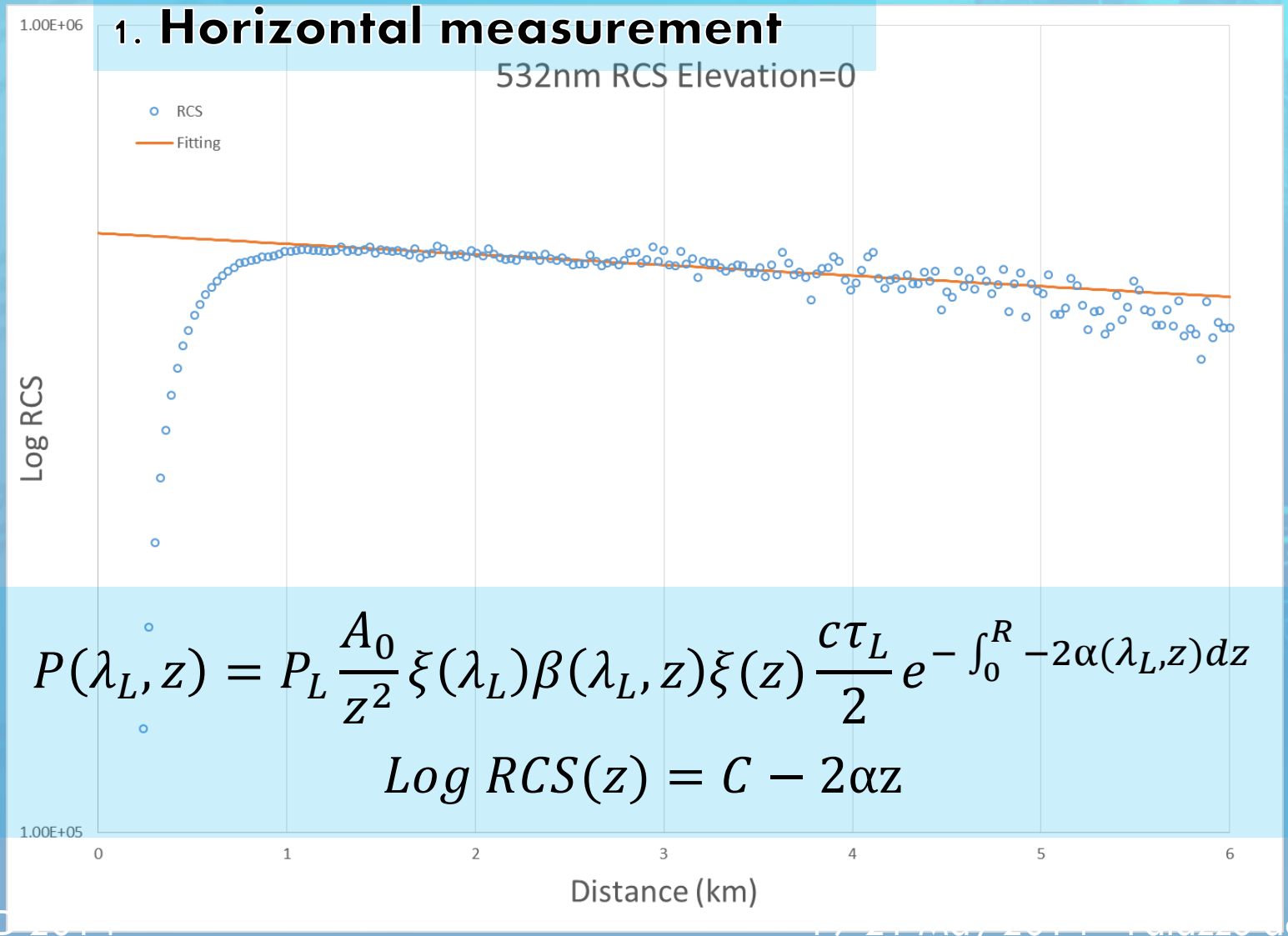
1. Horizontal measurement



Calibration and test

Overlap function determination

1. Horizontal measurement

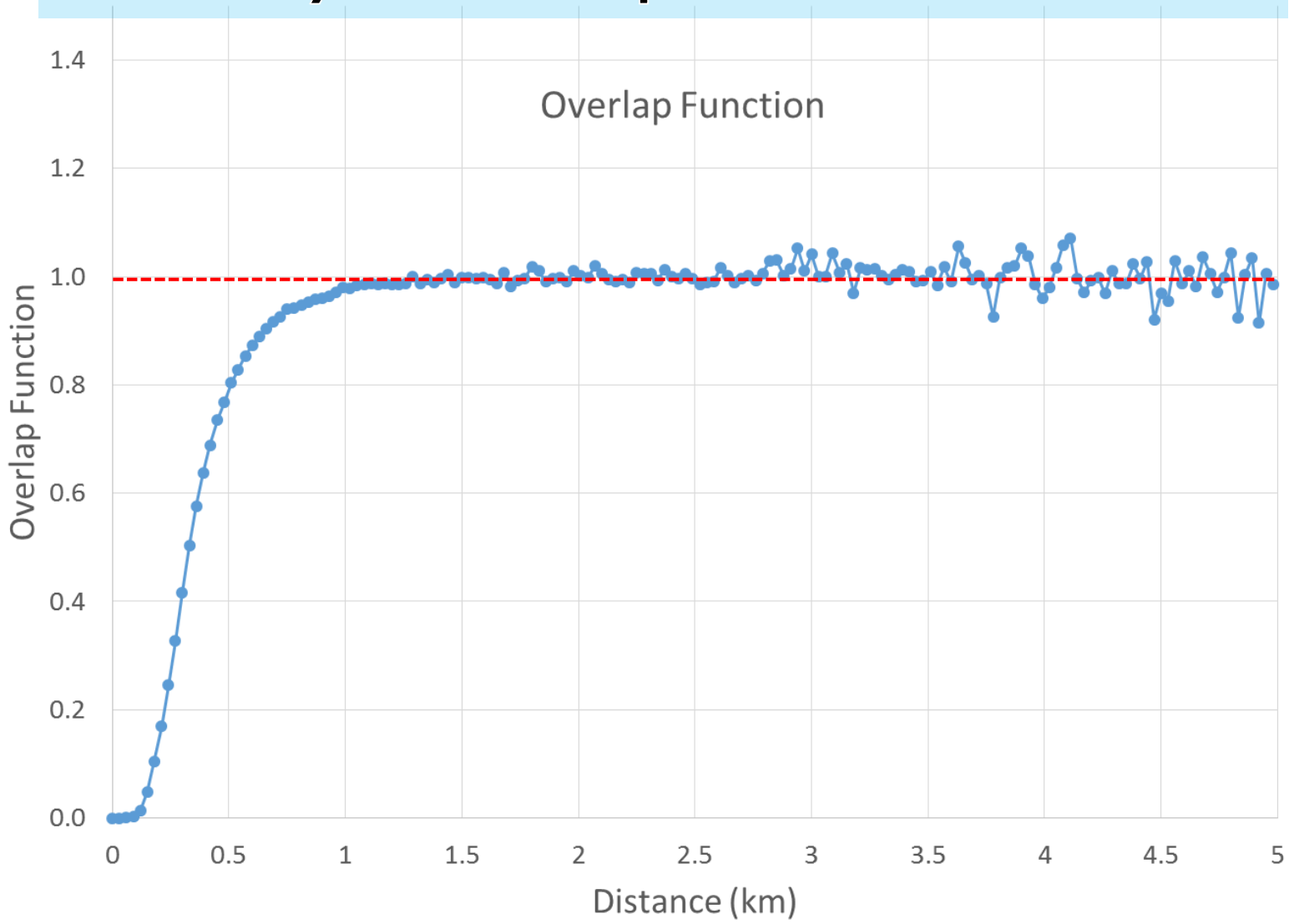


$$P(\lambda_L, z) = P_L \frac{A_0}{z^2} \xi(\lambda_L) \beta(\lambda_L, z) \xi(z) \frac{c\tau_L}{2} e^{-\int_0^R -2\alpha(\lambda_L, z)dz}$$

$$Log\ RCS(z) = C - 2\alpha z$$

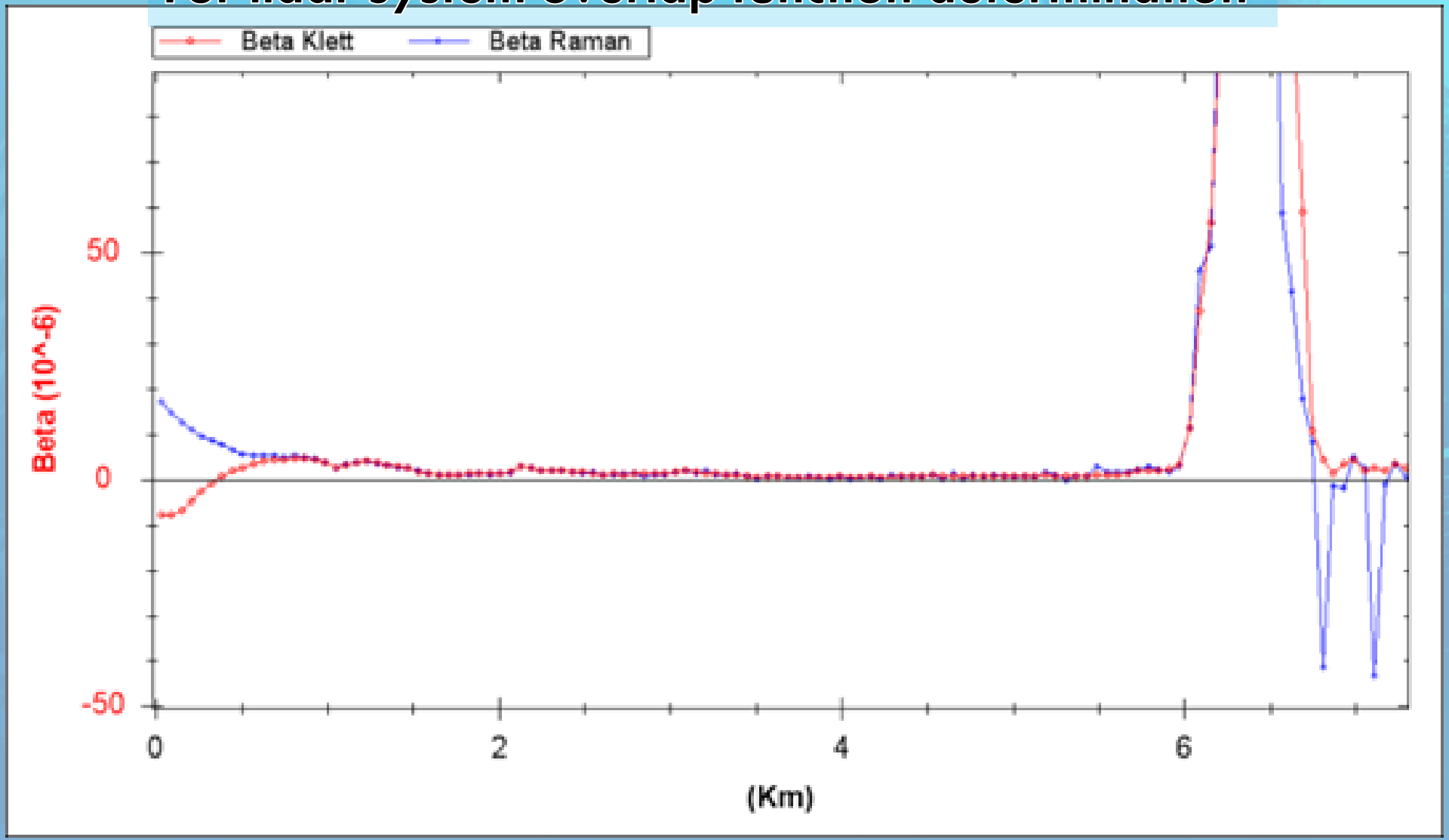
1. Horizontal measurement

For lidar system overlap function determination



2. From Raman and Klett aerosol backscatter iterative

For lidar system overlap function determination



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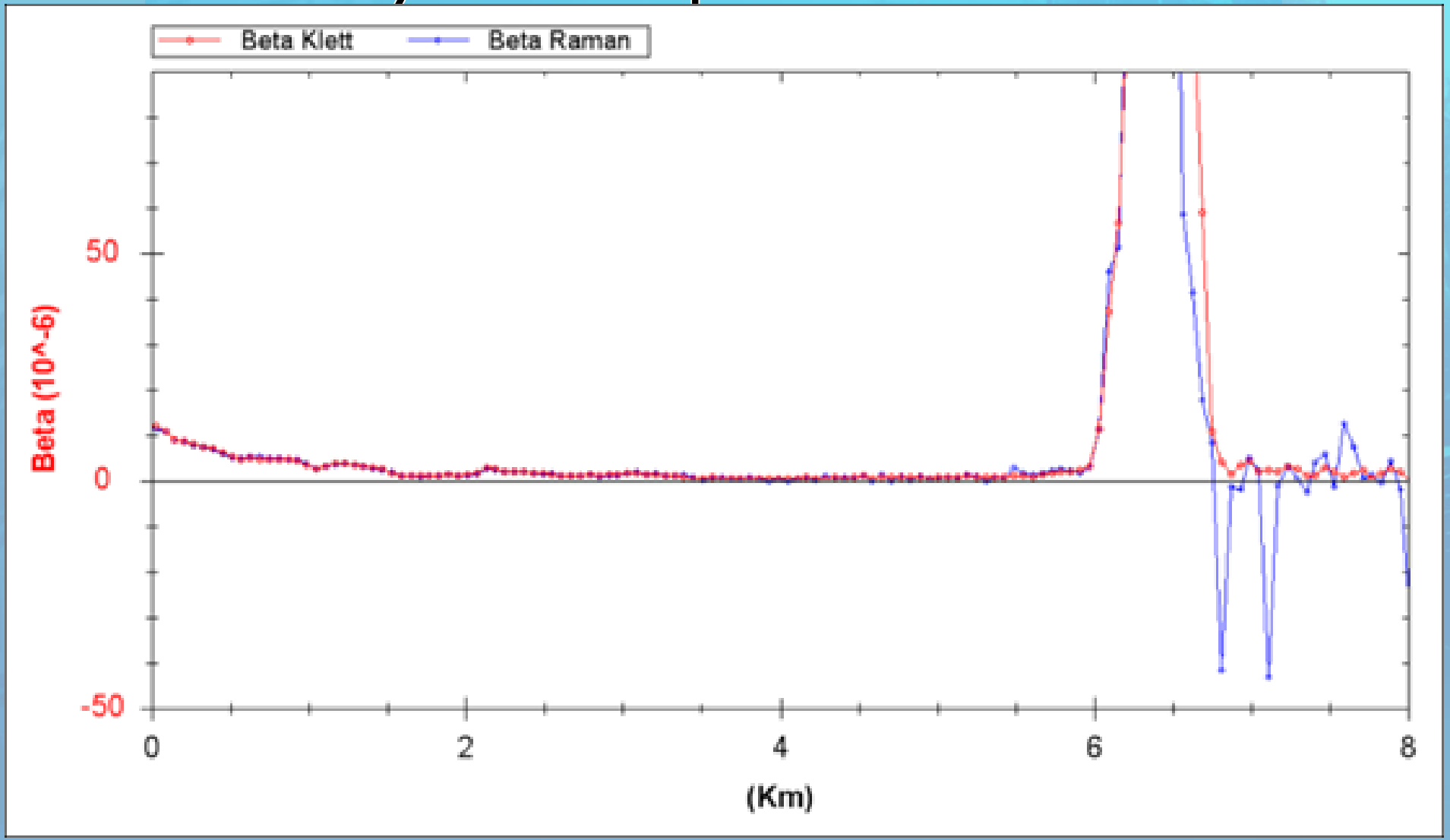

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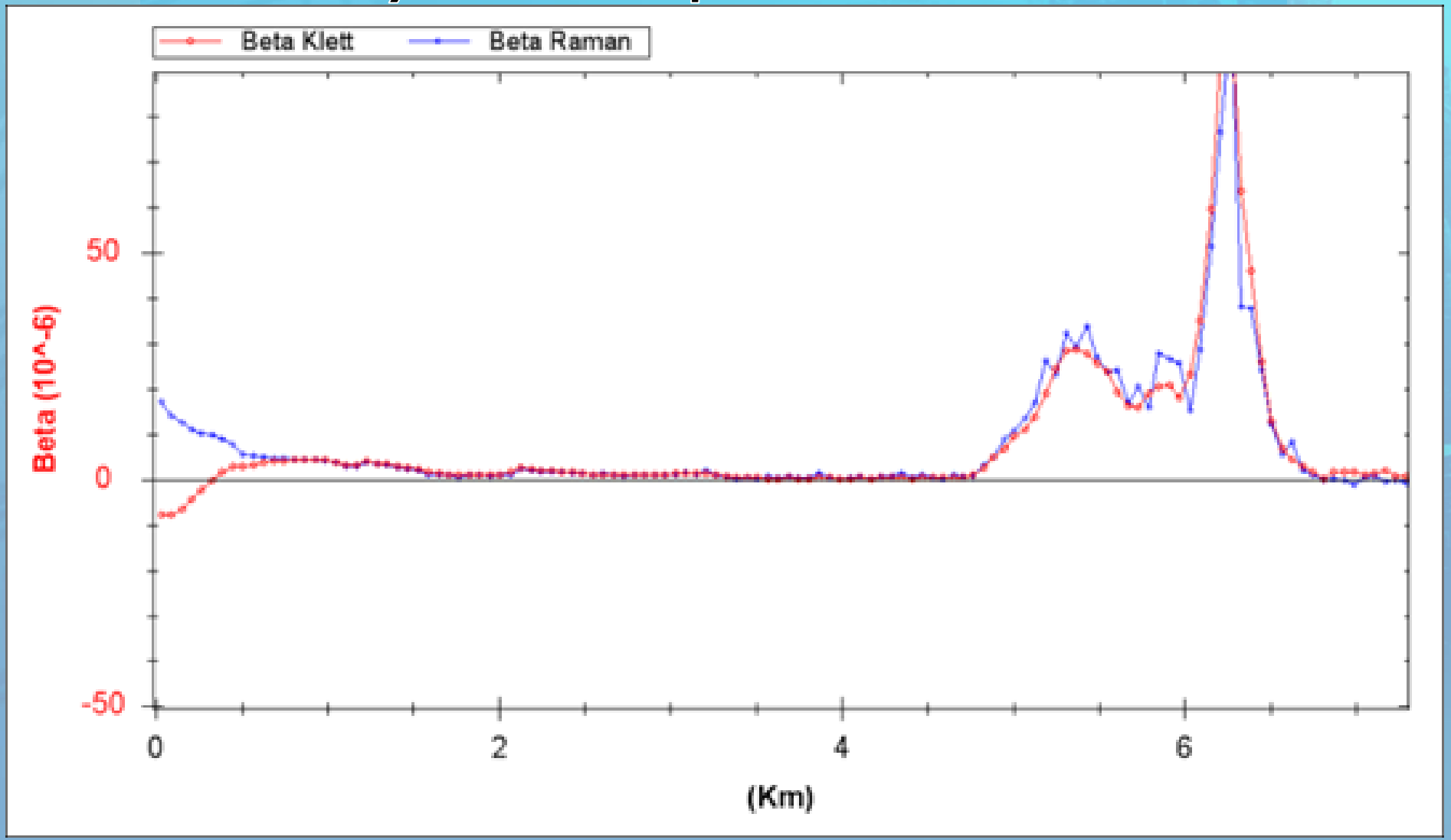

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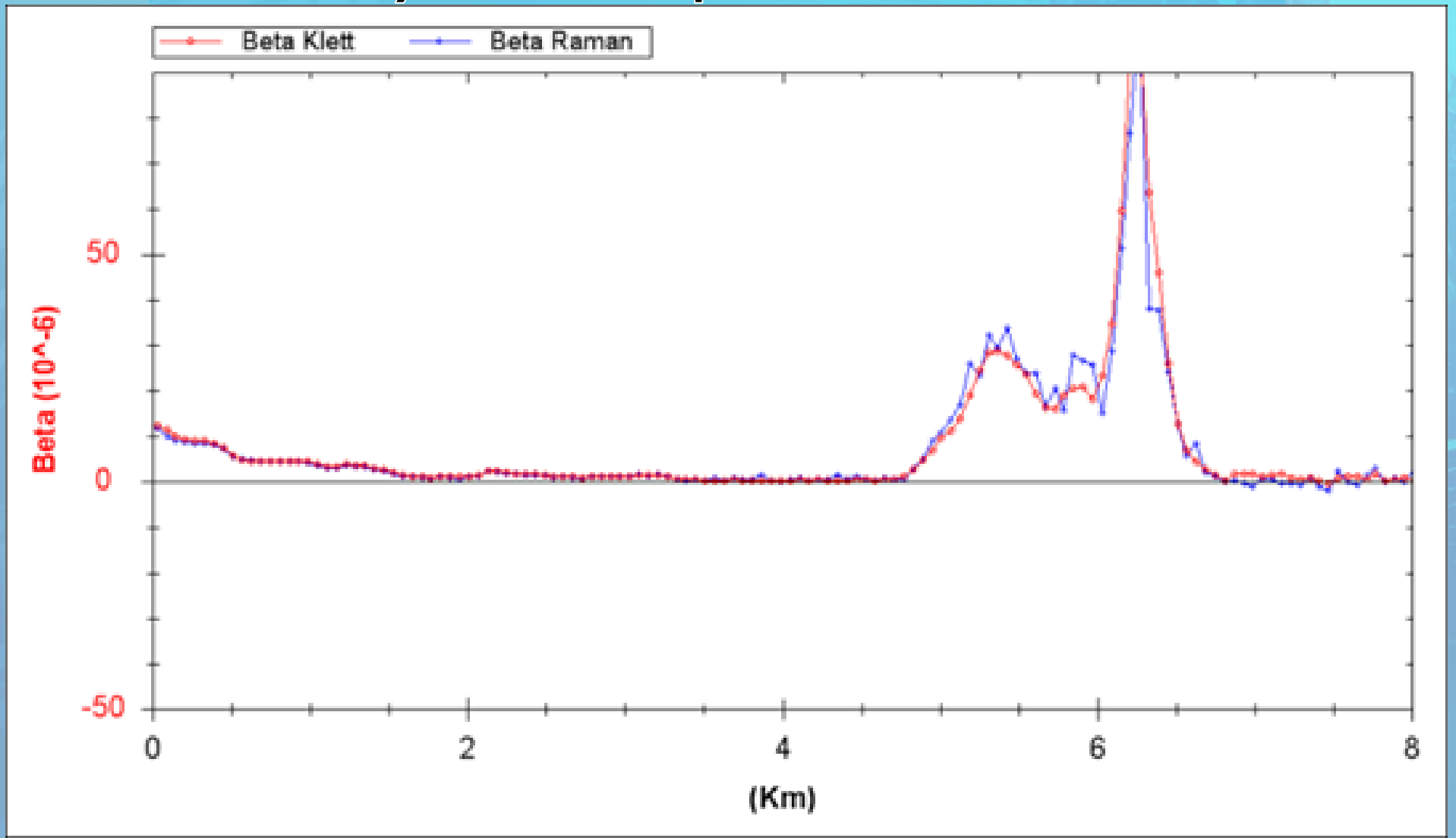

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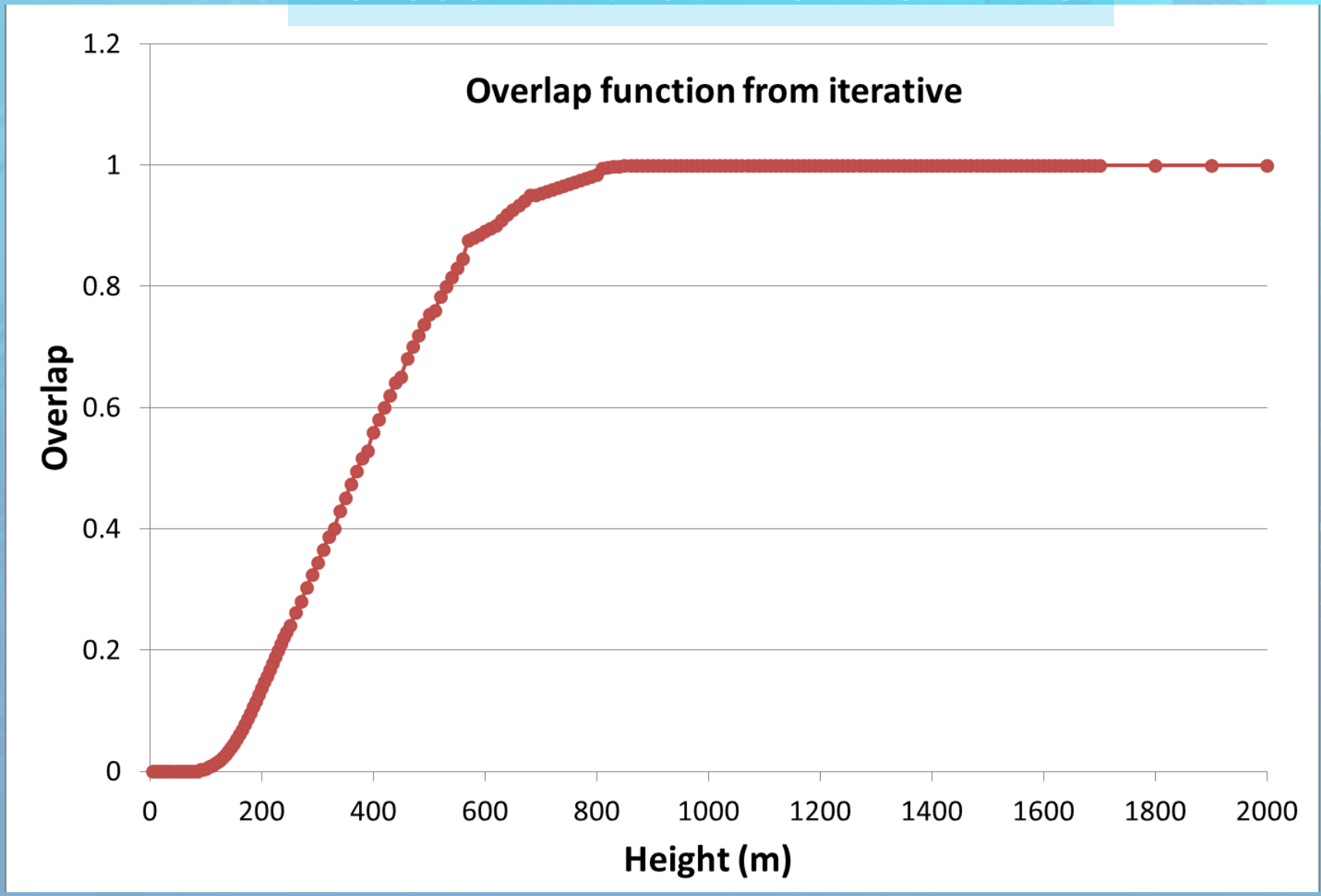


Multiwavelength channel calibration

Aerosol Backscattering Color Index – CI

$$CI = \frac{\log(\beta_{532}/\beta_{355})}{\log(355/532)}$$

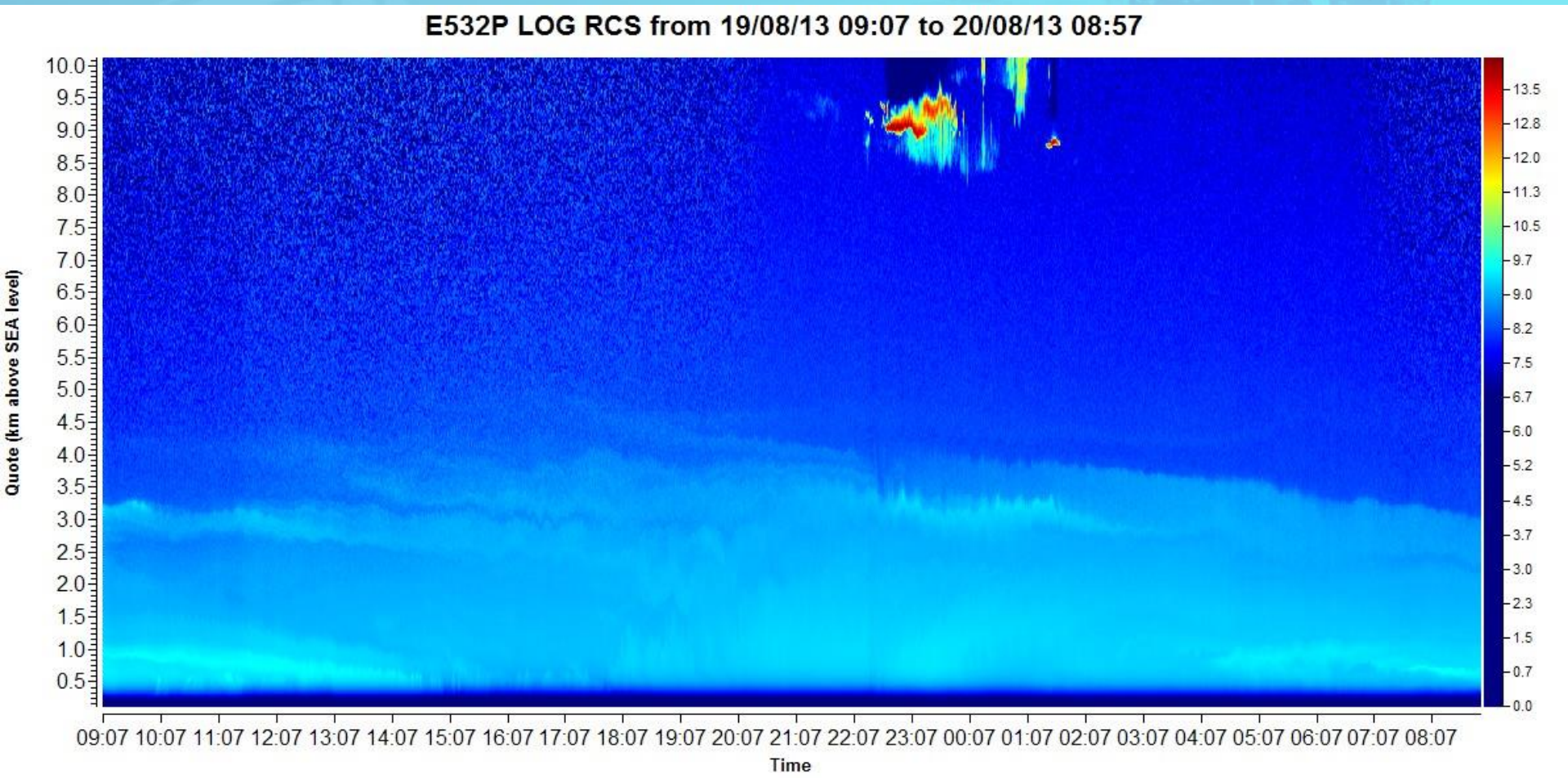
Typical CI from -1 to 4

Cirrus cloud is ideal object for the calibration of different wavelength channel

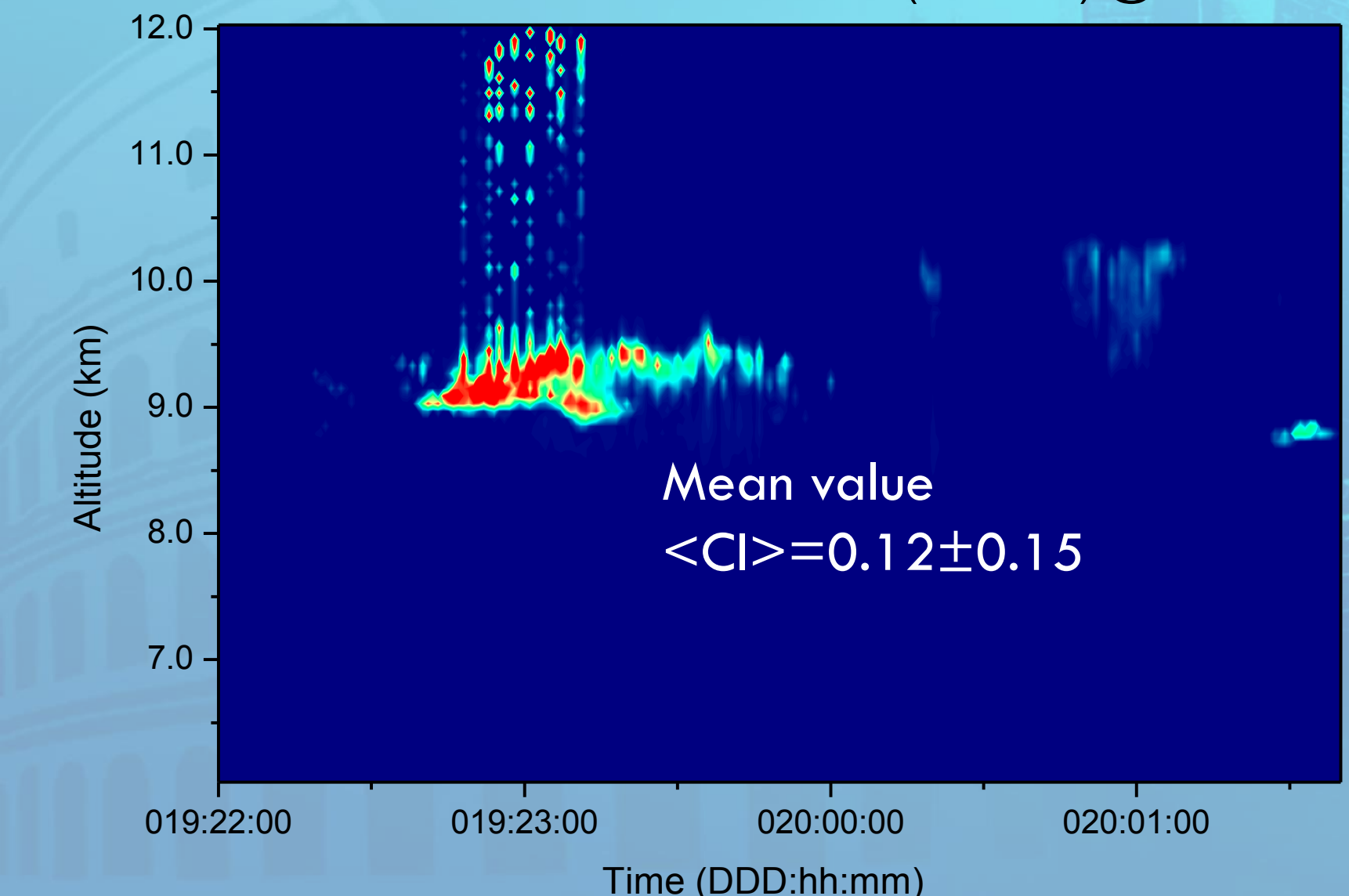
$$\beta_{355} = \beta_{532} = \beta_{1064}$$

$$CI = 0$$

Multiwavelength channel calibration

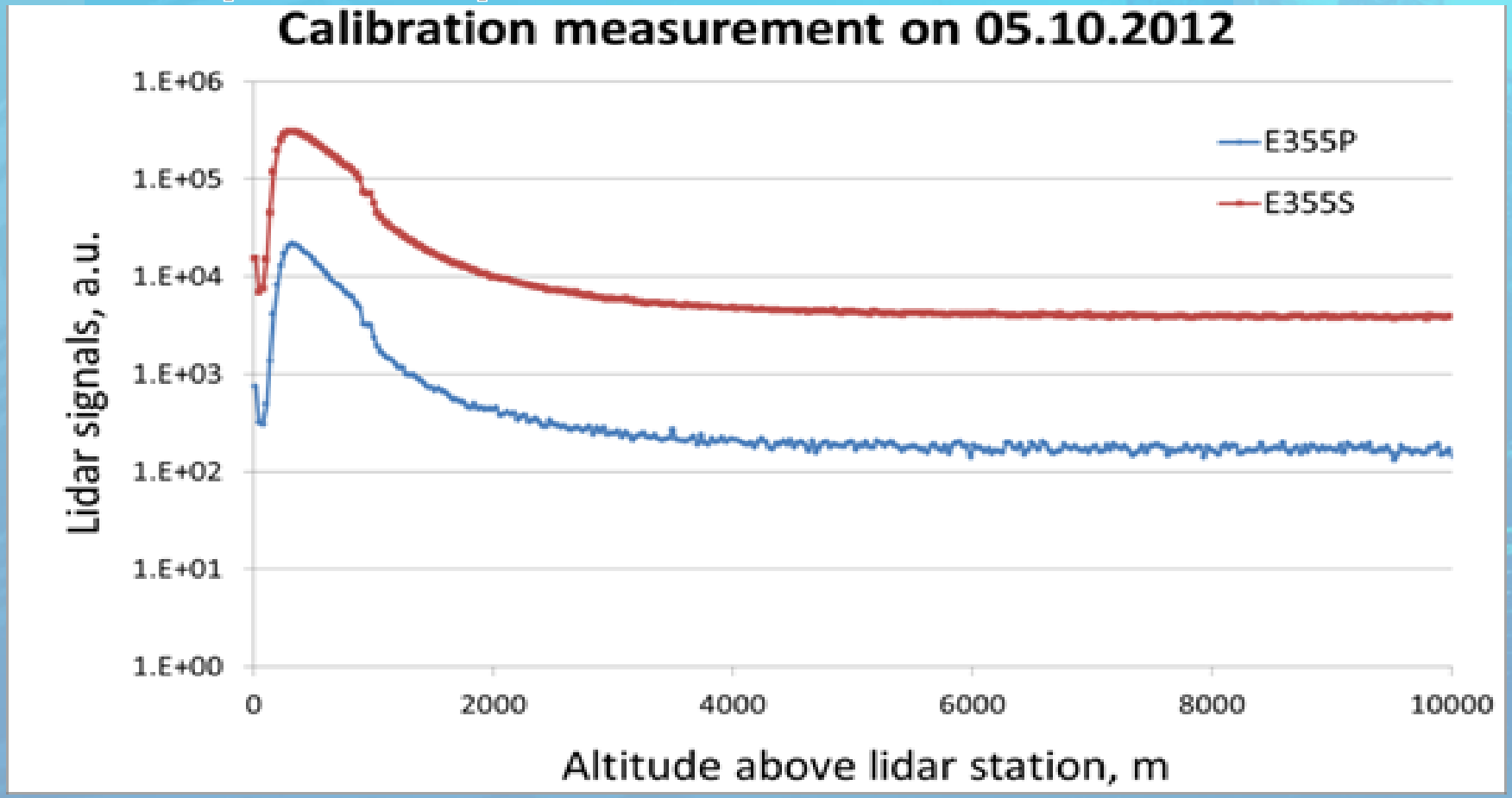


Multiwavelength channel calibration



Depolarization Calibration

1. Depolarizer plate measurement

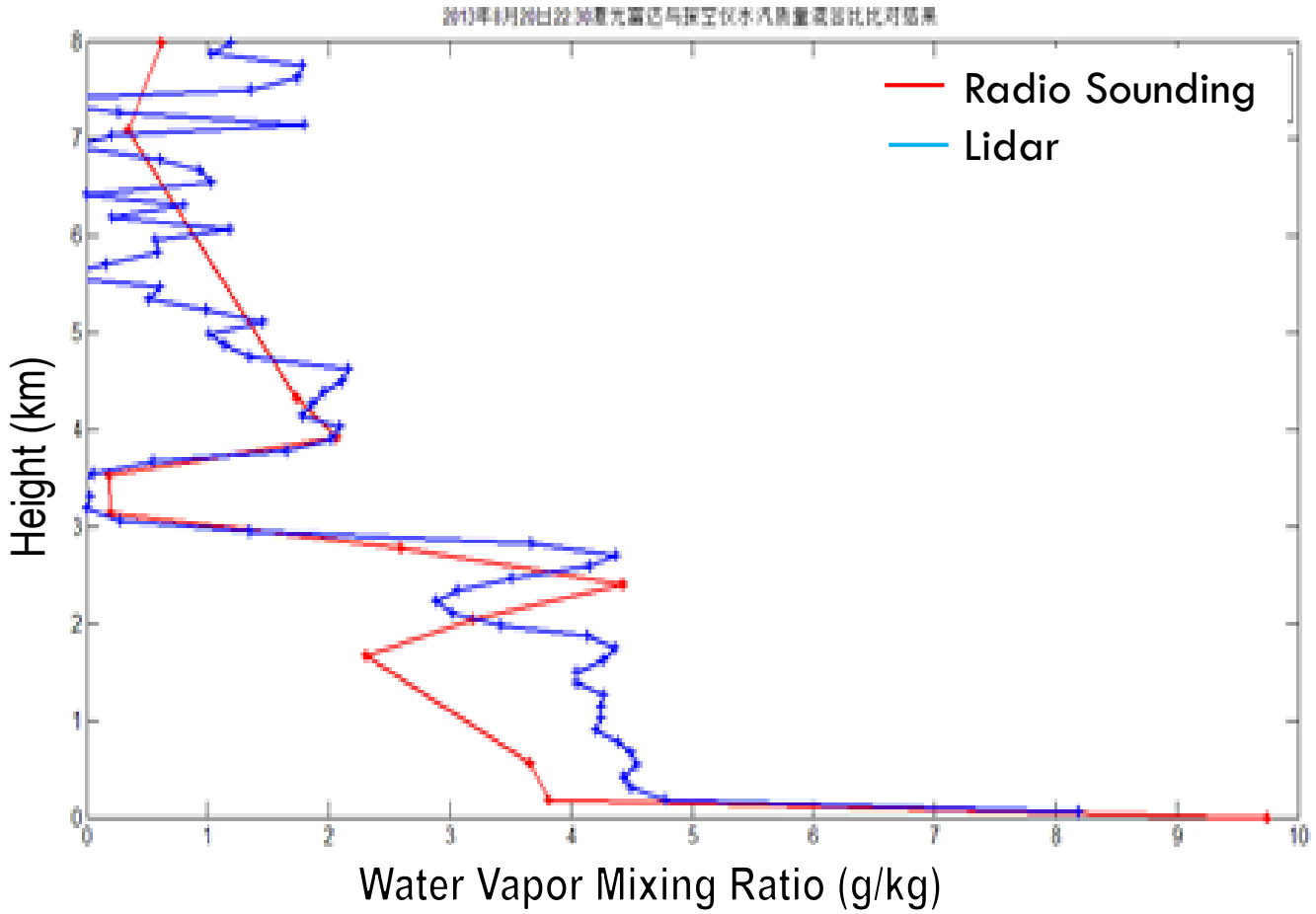


Example of measurement for polarization calibration

Difference in the signal amplitude can be due to the different gain of the photomultiplier used or to the different transmission optical efficiency

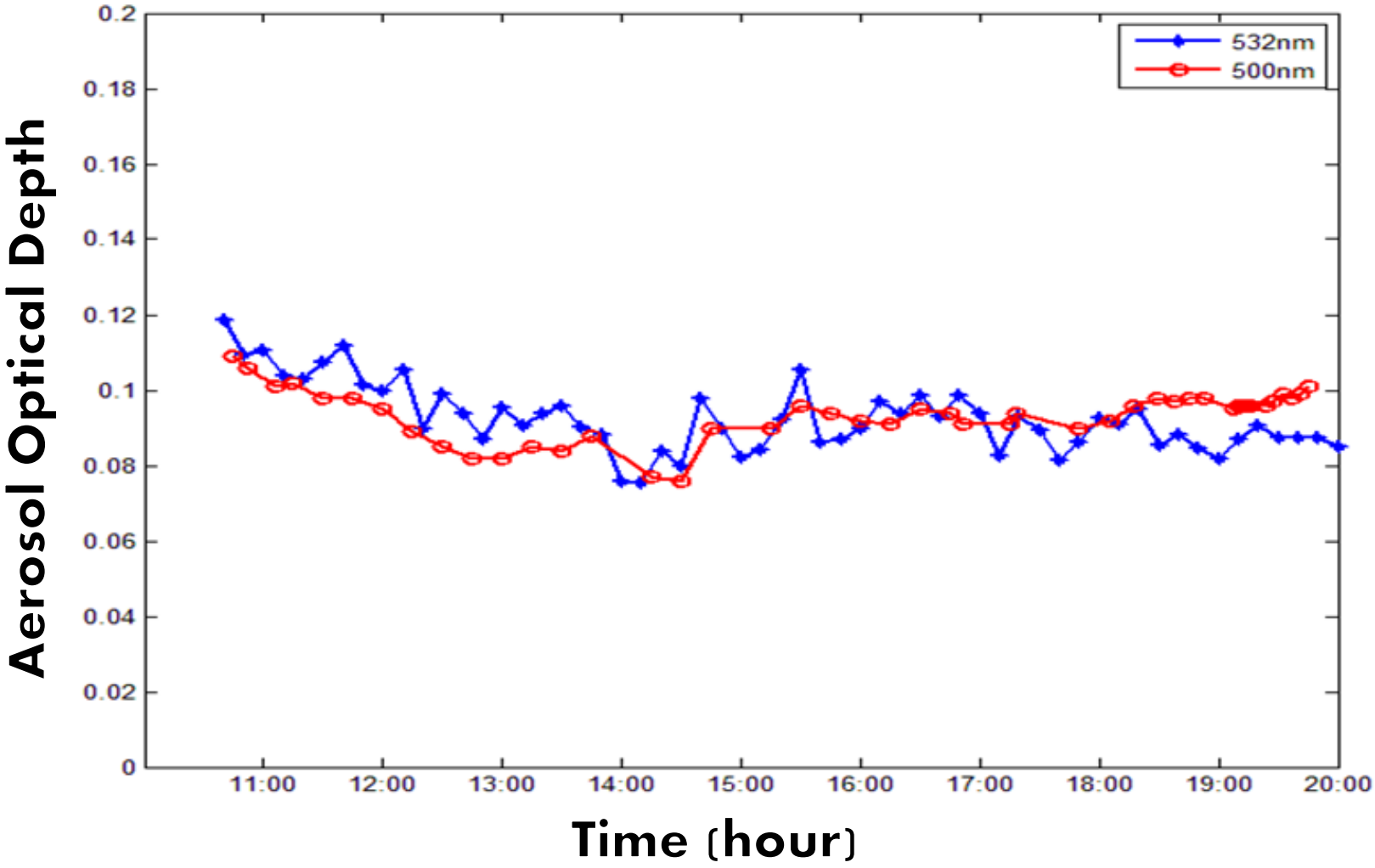
Water Vapor Mixing Ratio Test

Compare with radio sounding



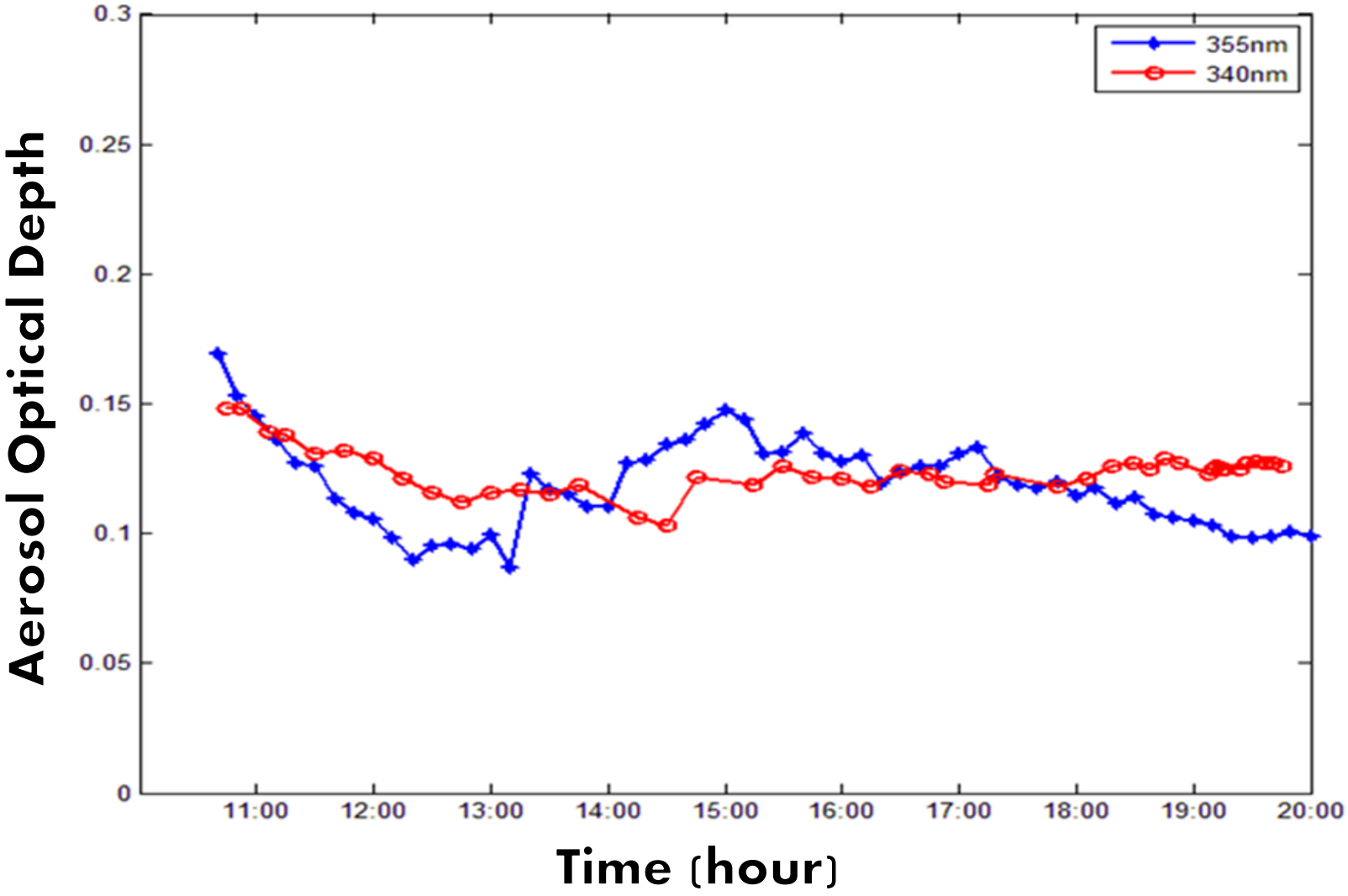
Comparision with Sun-photometer

Sun-photometer CE318 500nm, Aug. 20, 2013

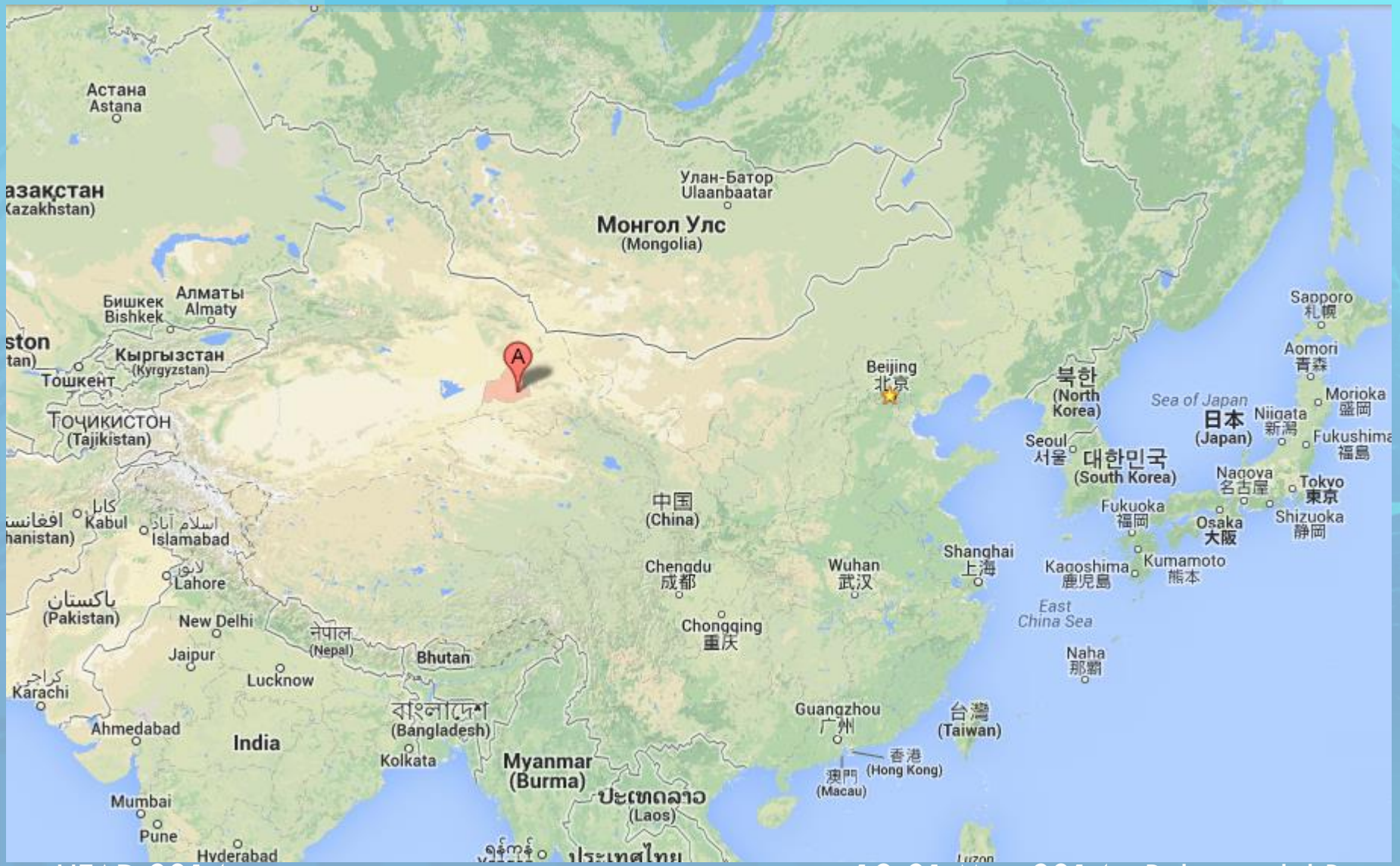


Comparison with Sun-photometer

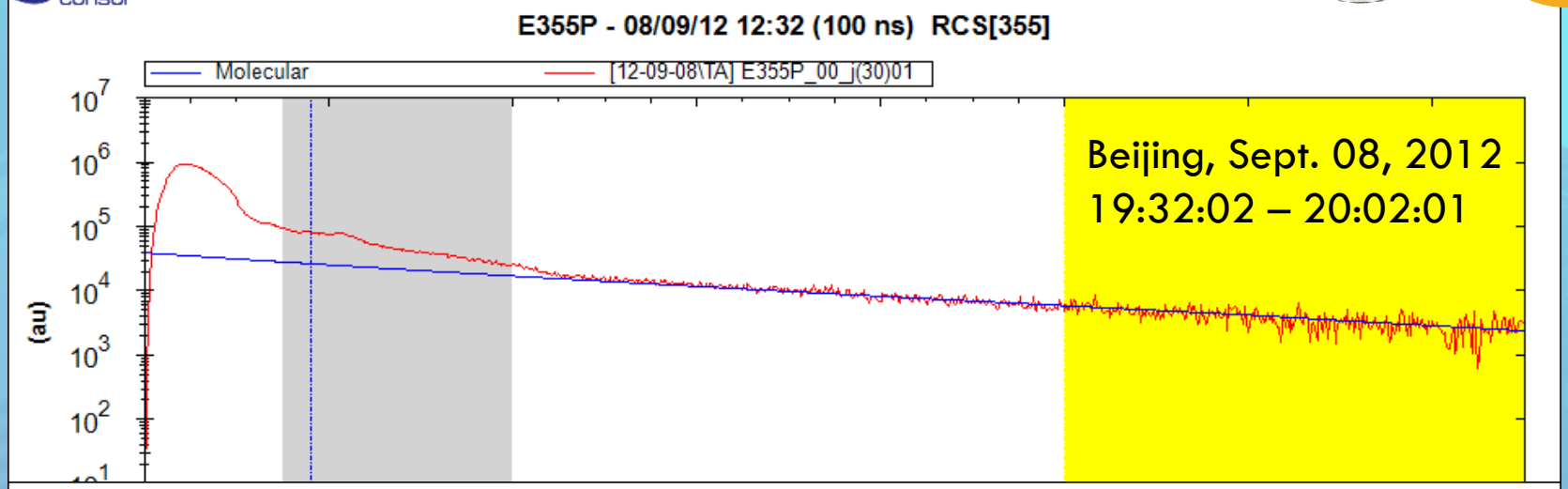
Sun-photometer CE318 340 nm, Aug. 20, 2013

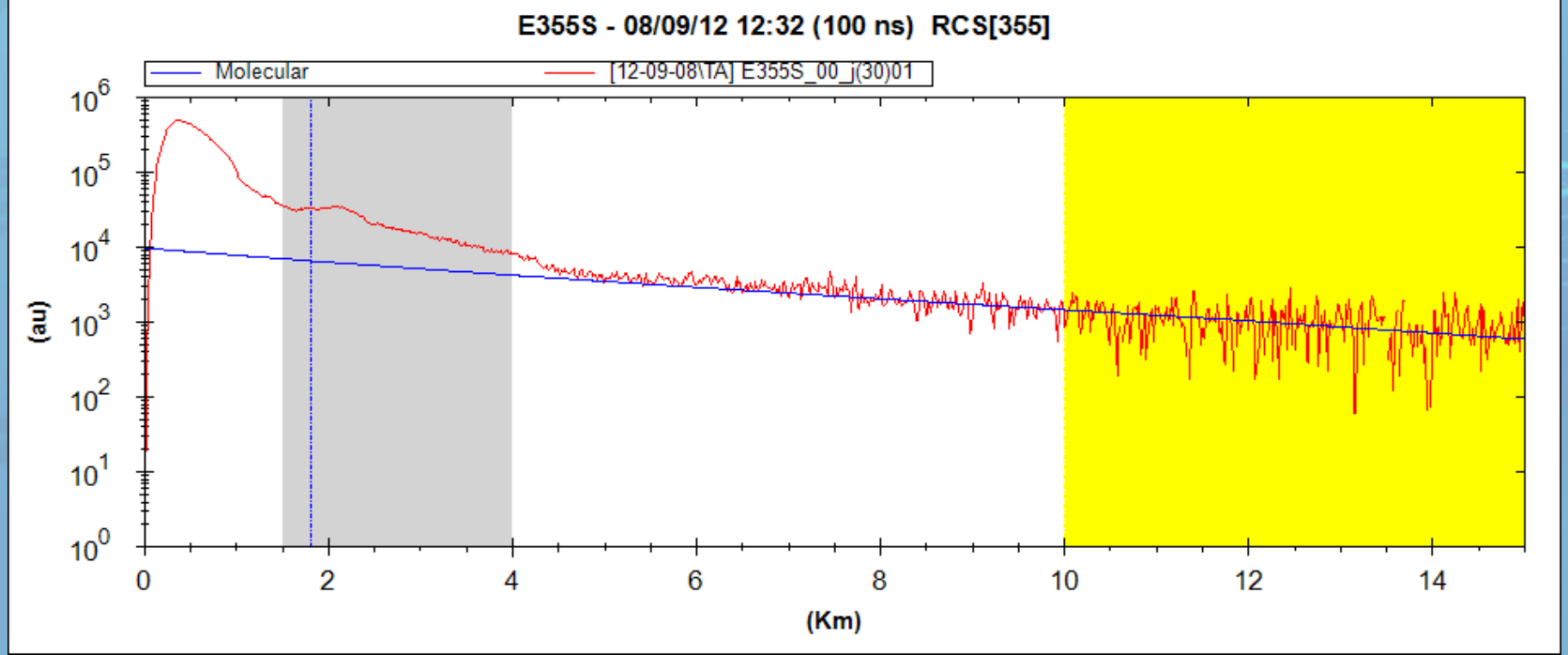


Results from the field measurements



Results in Beijing





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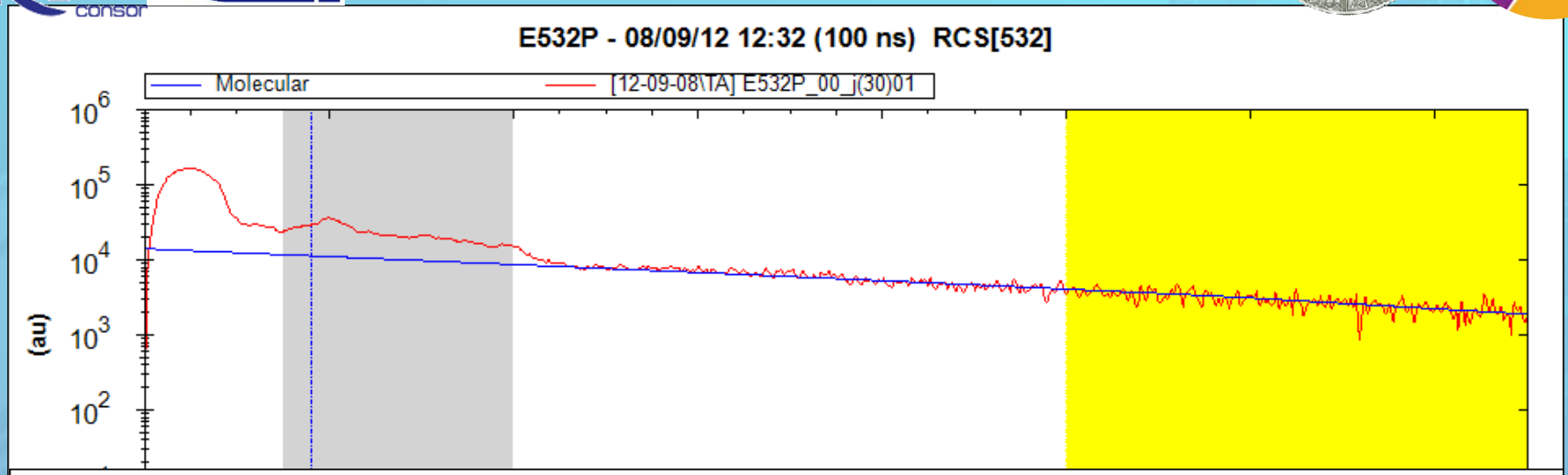

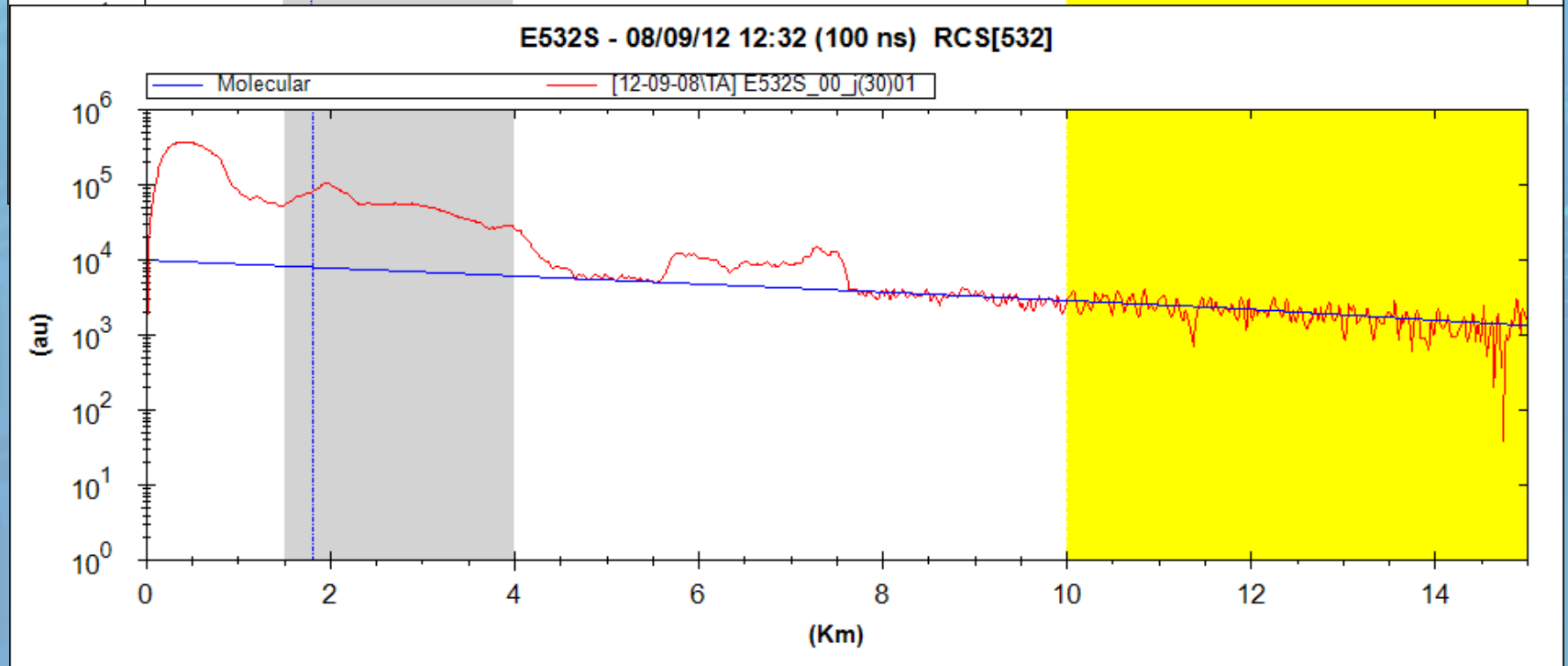

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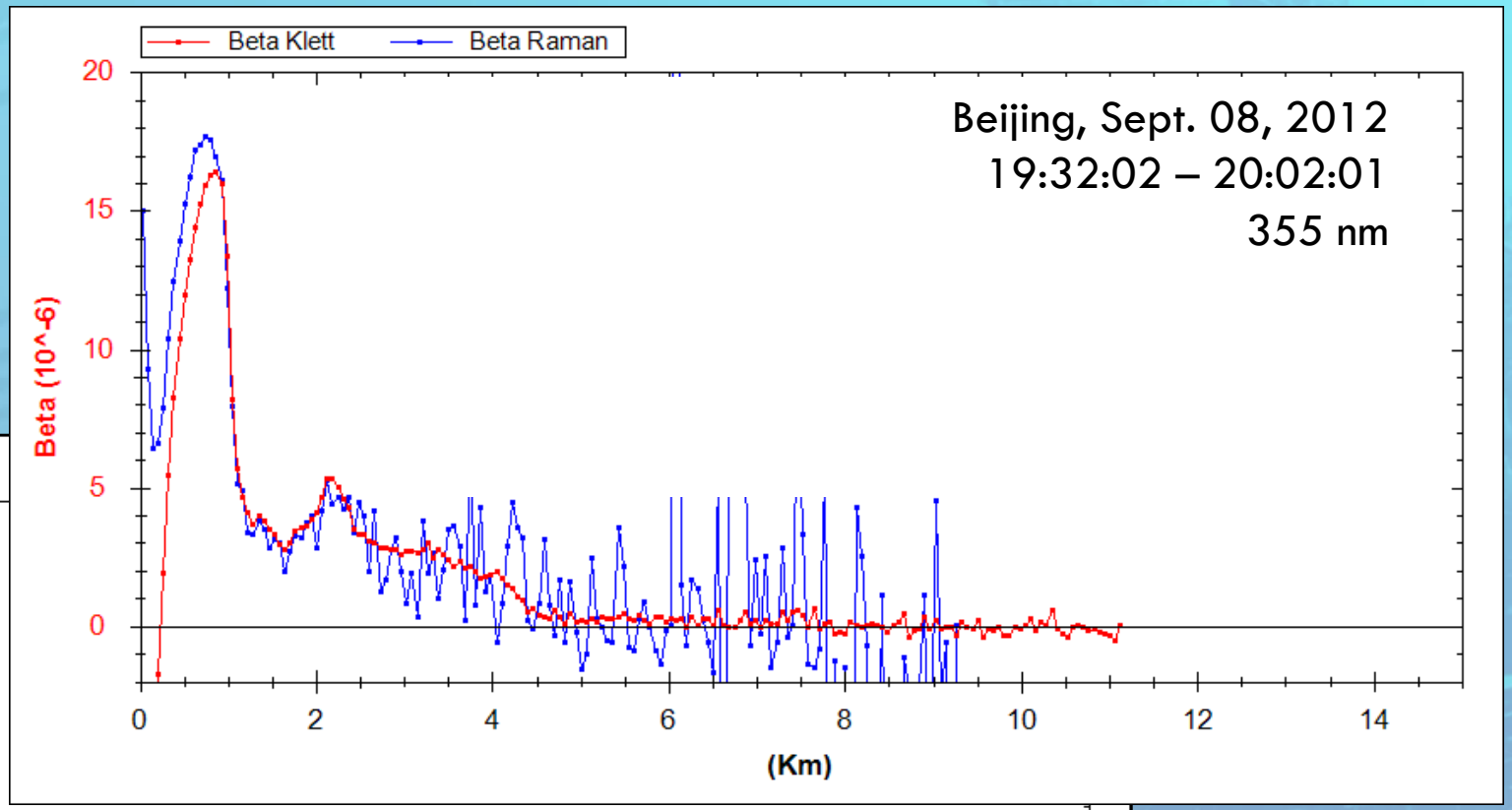

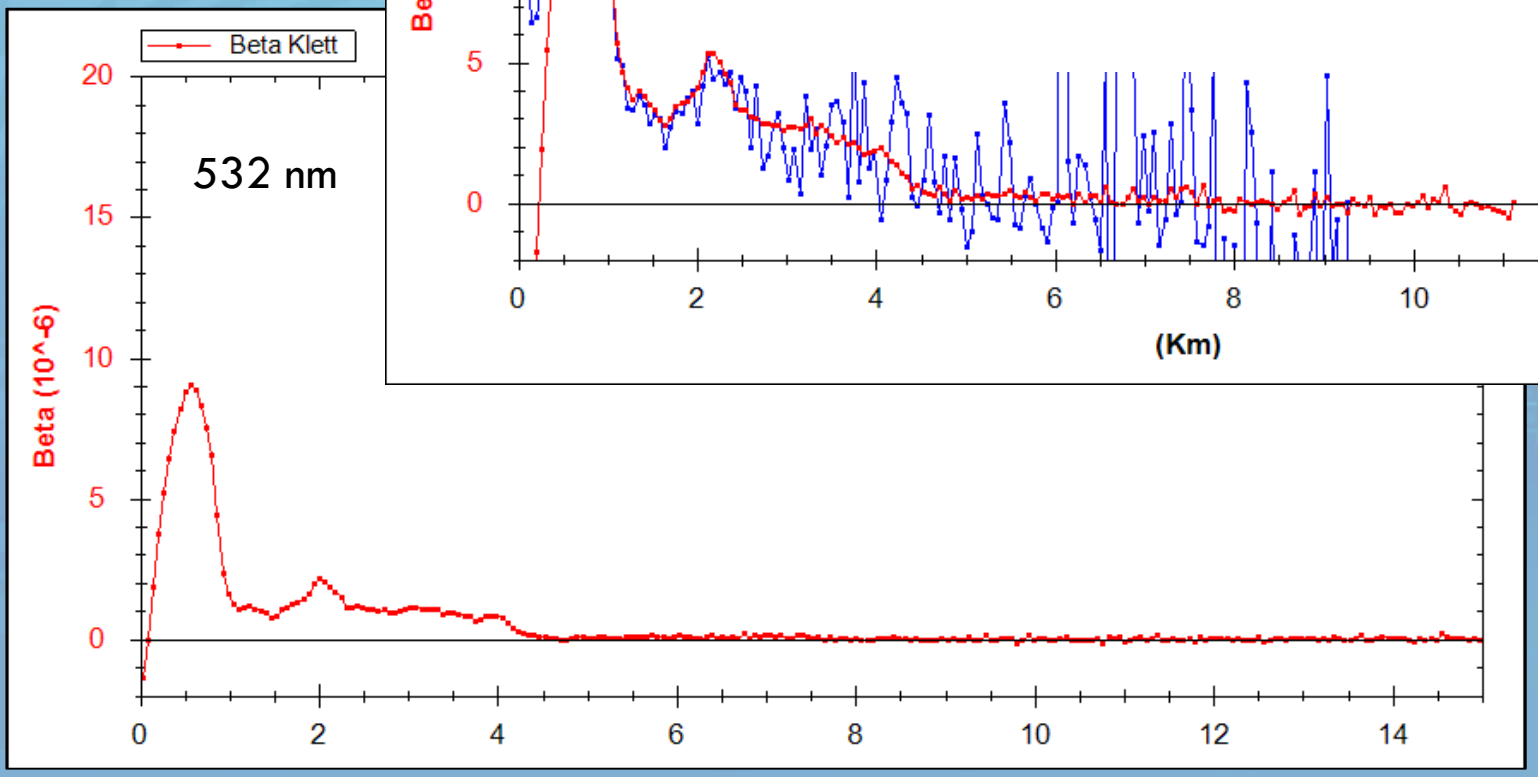

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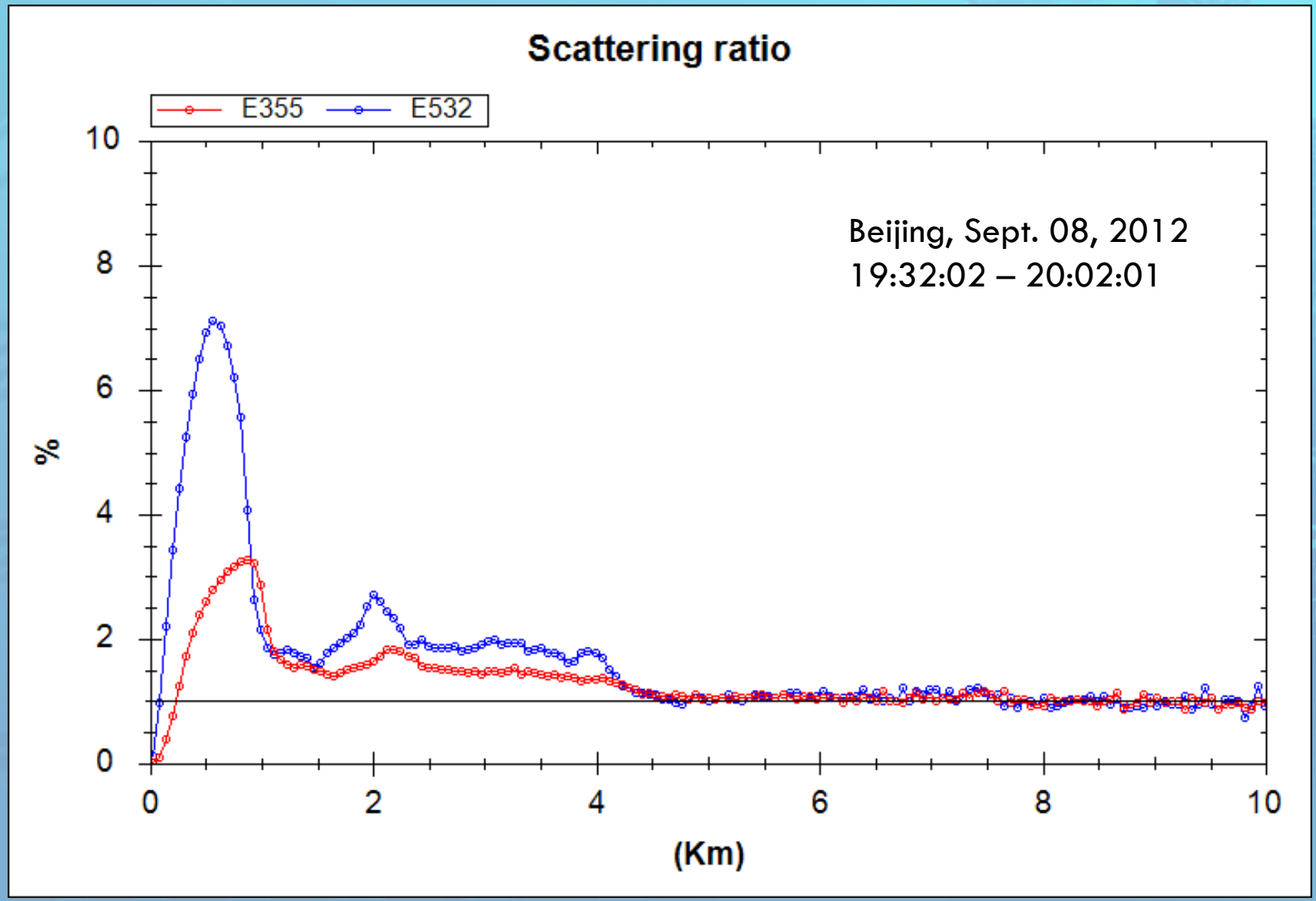

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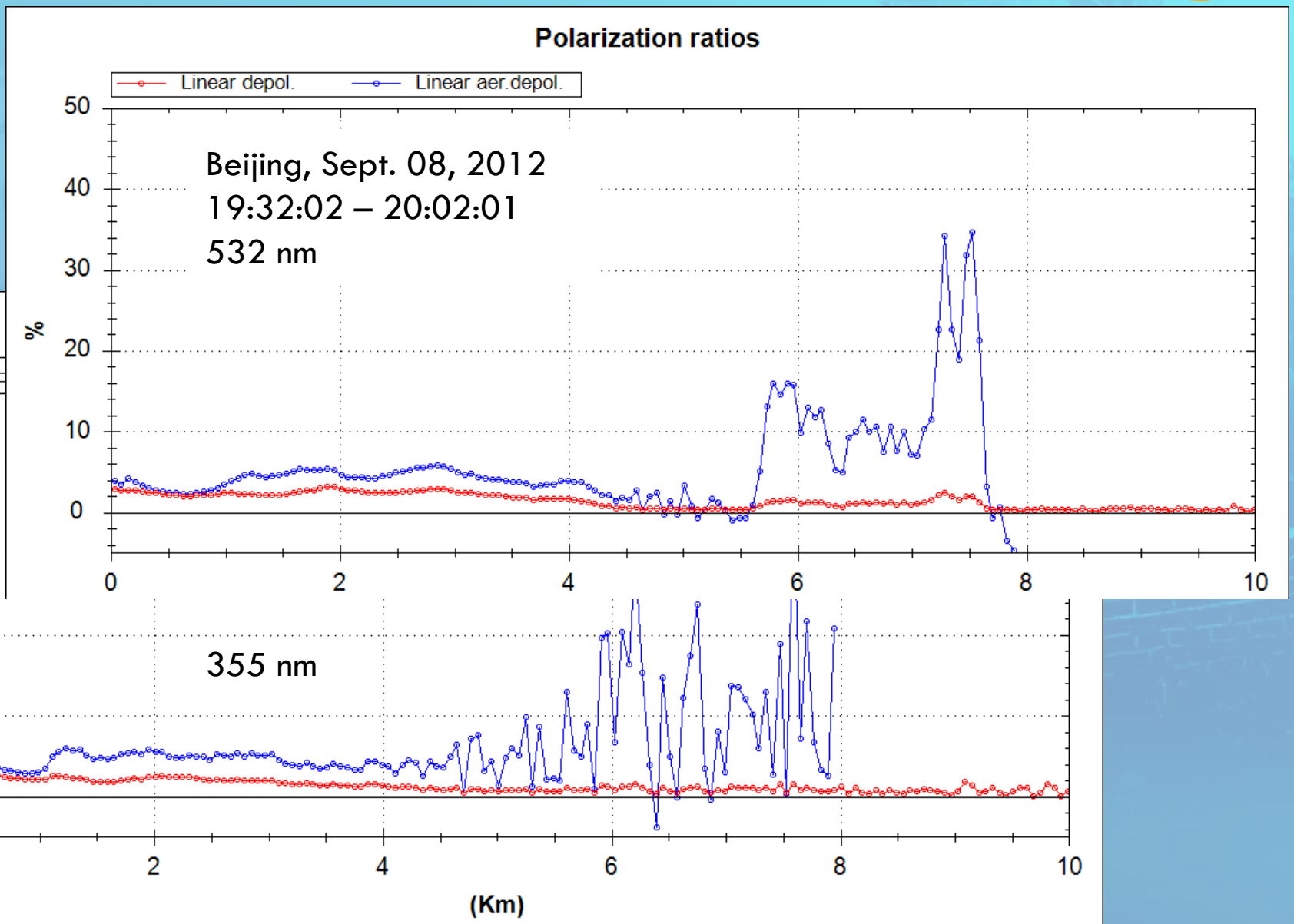

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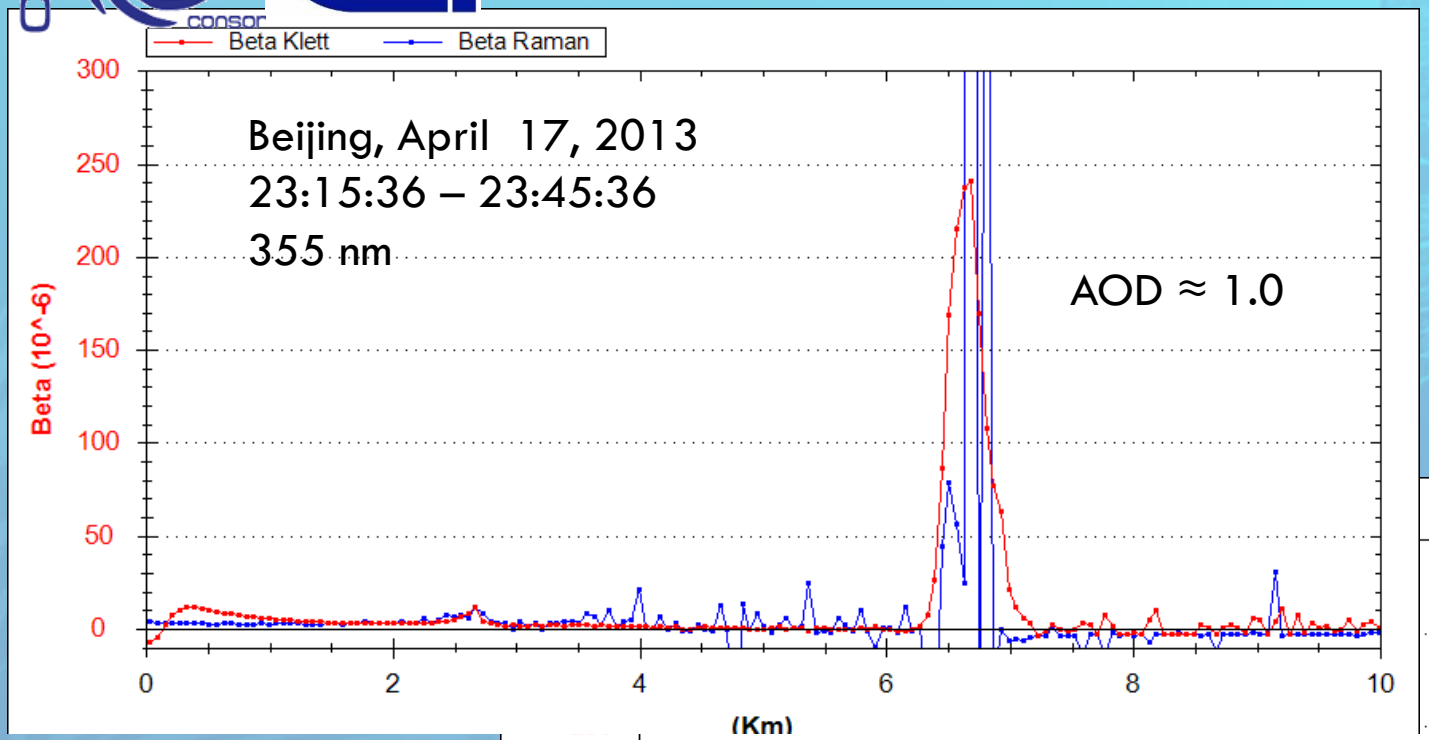
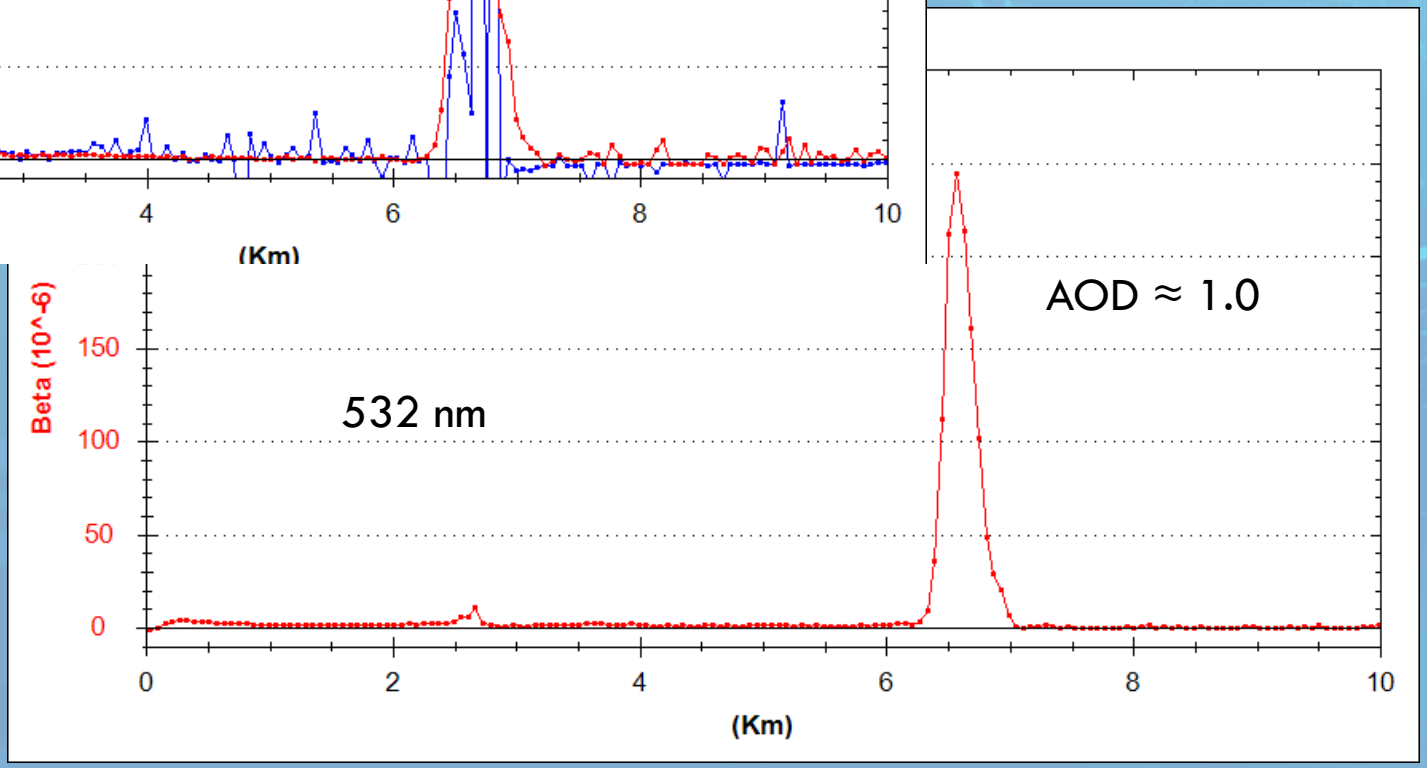
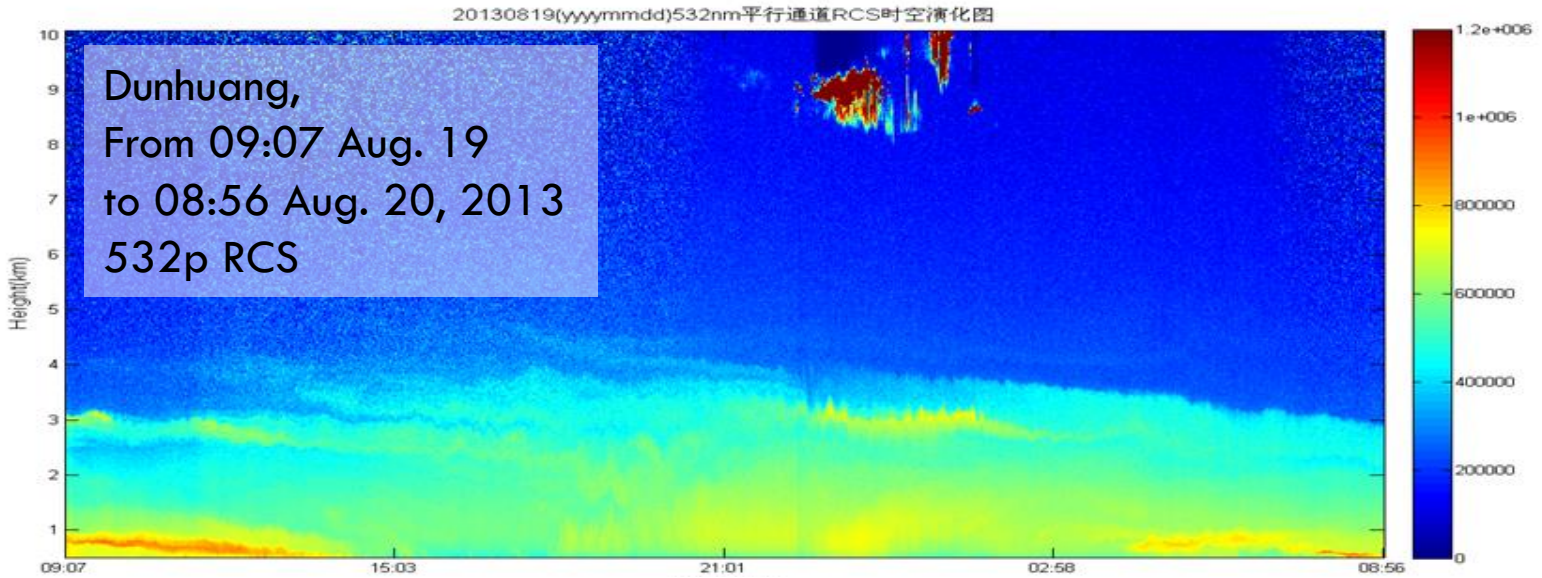


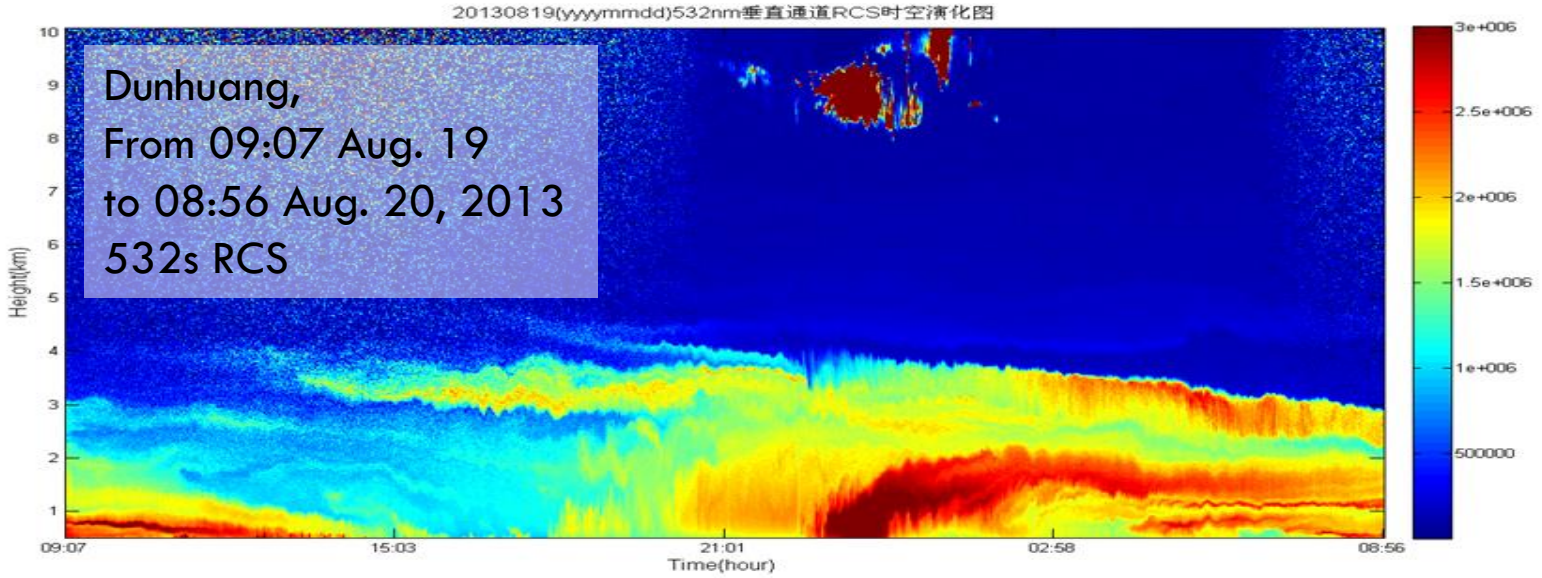


Results in Dunhuang

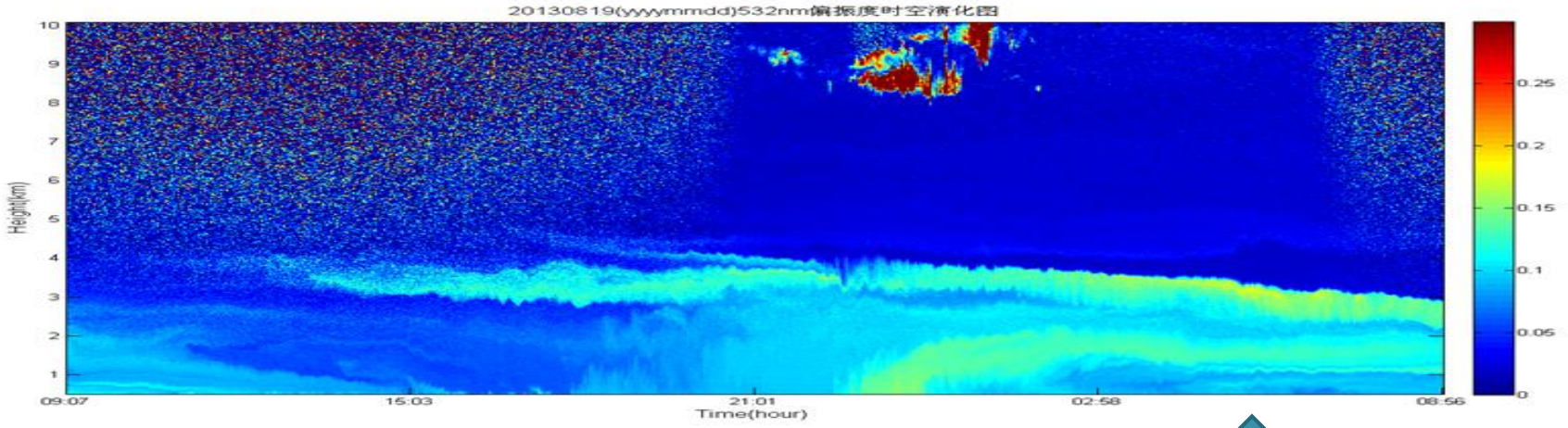
Dunhuang, @ 40.8N , 94.41E

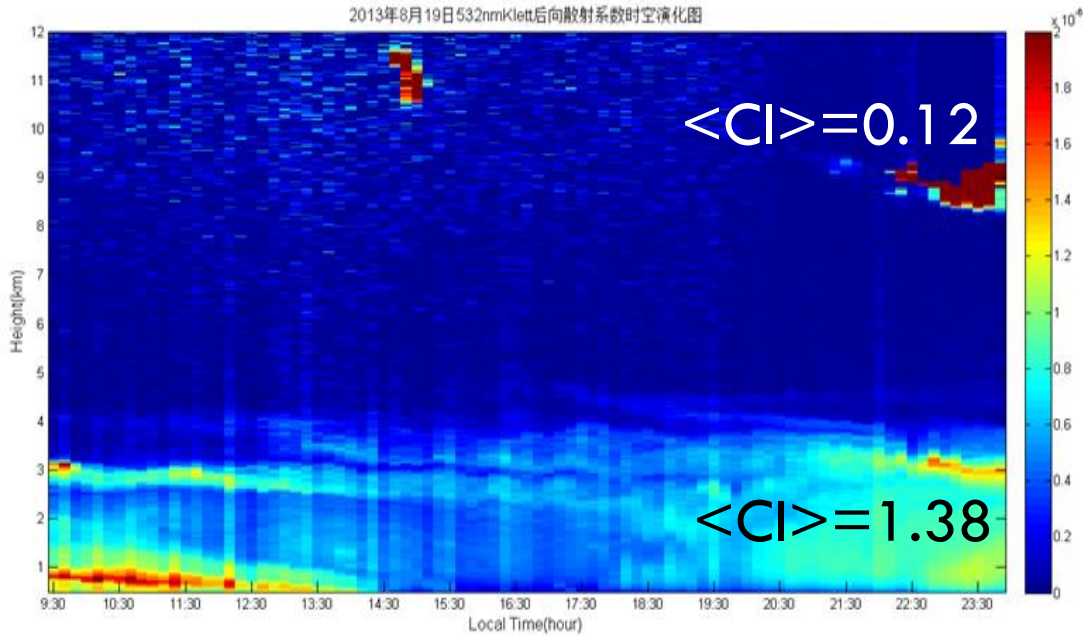
Results in Dunhuang





Results in Dunhuang



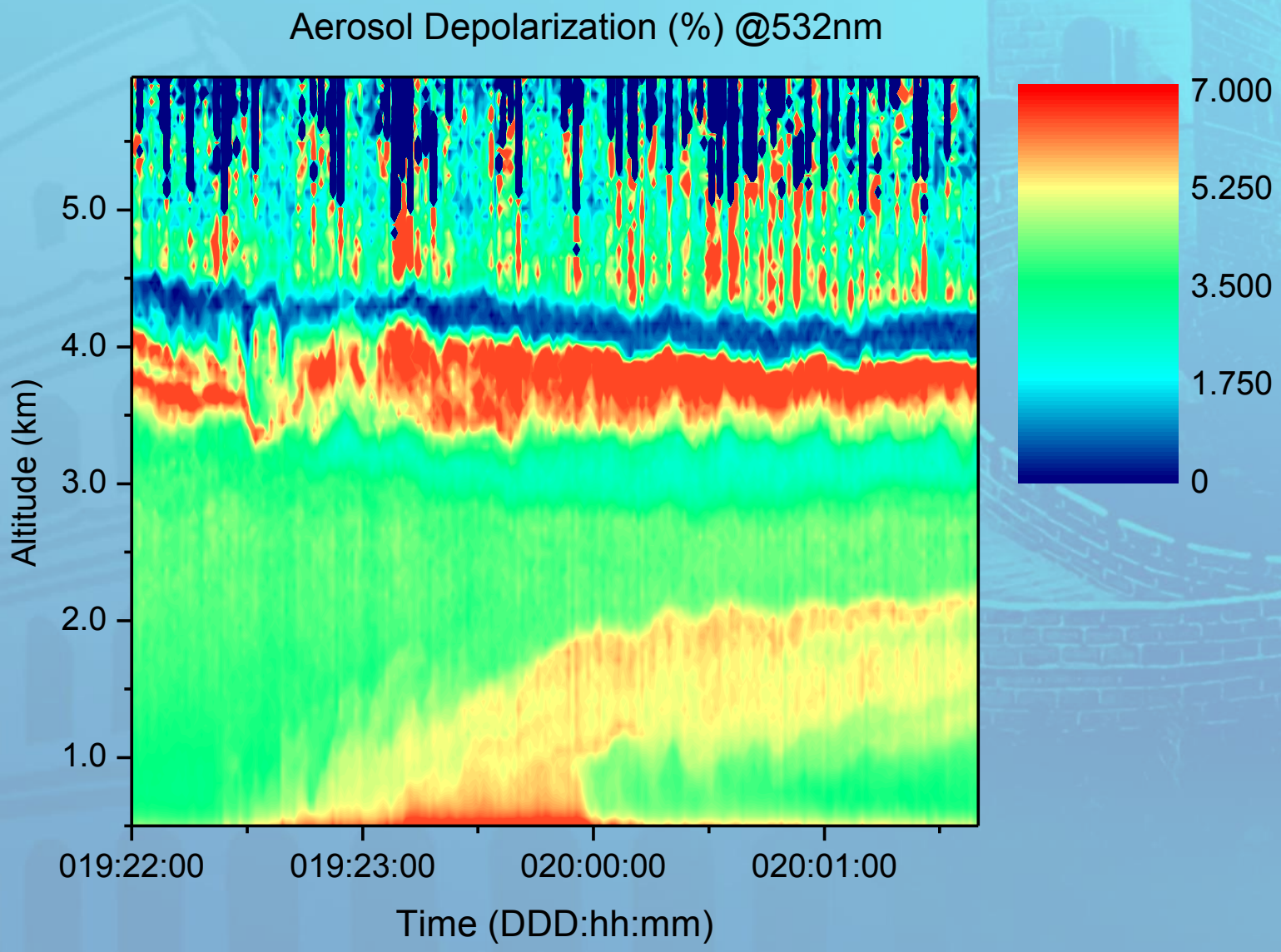


532 Depolarization

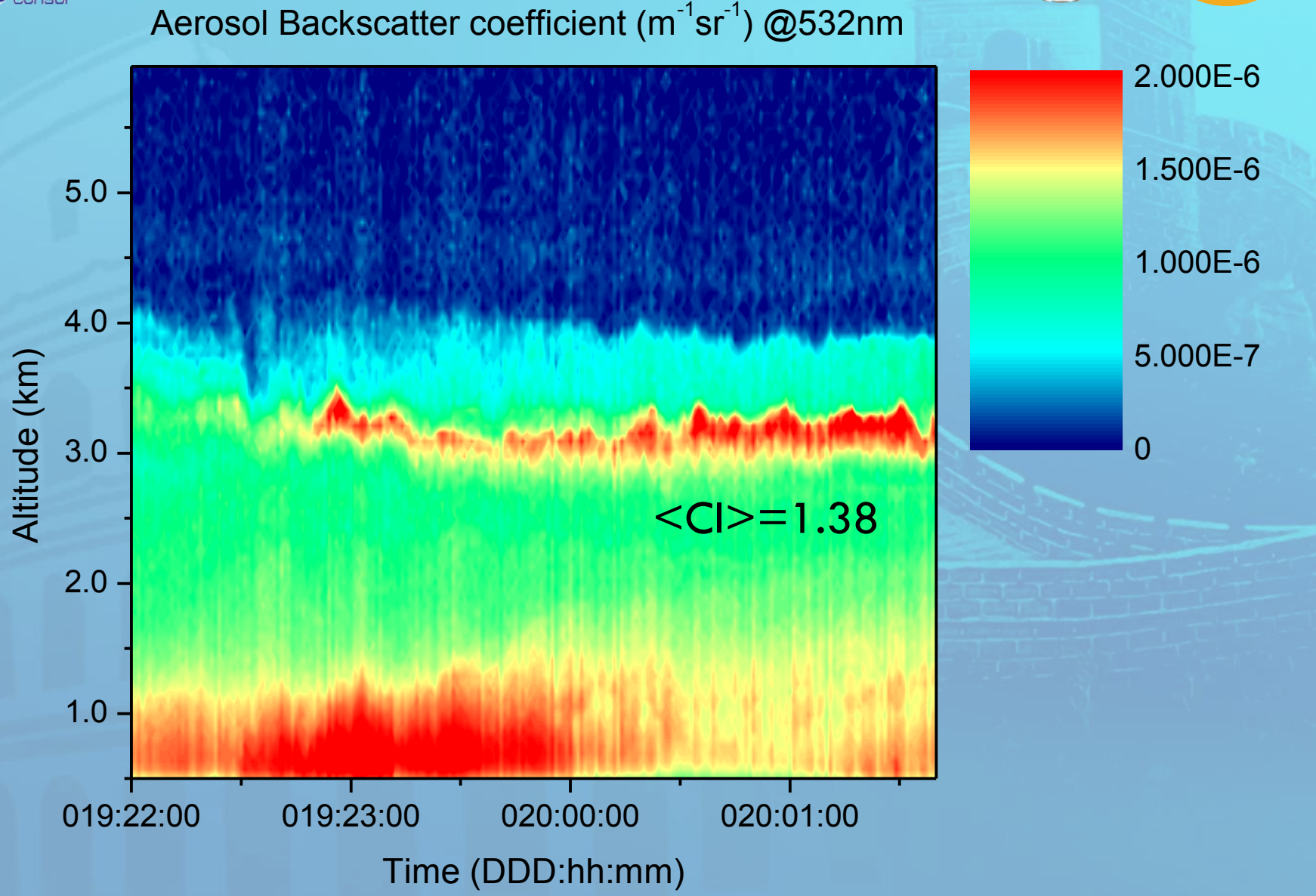
532 Backscattering

Dunhuang,
From 09:07 Aug. 19
to 08:56 Aug. 20, 2013

Results in Dunhuang



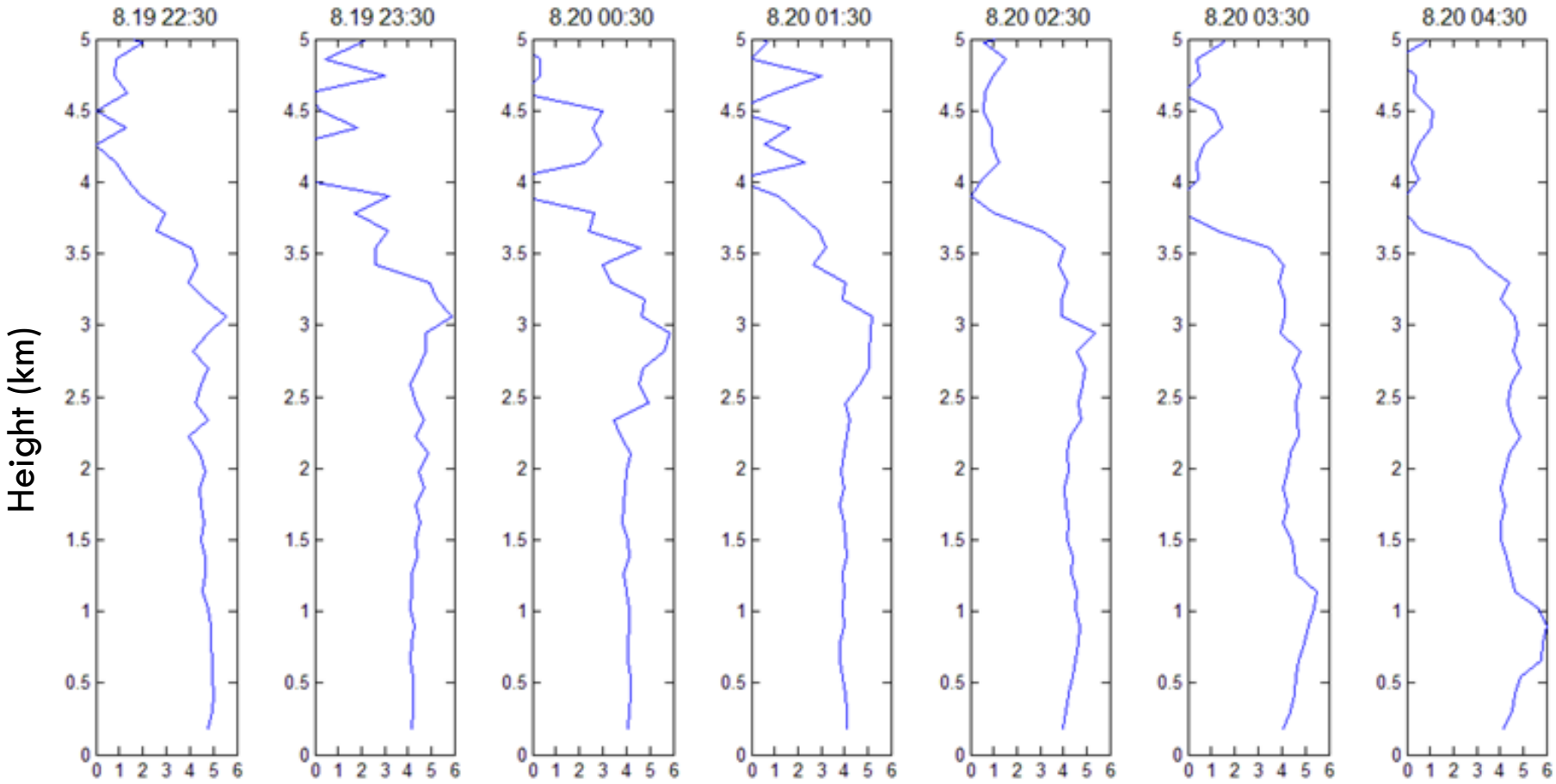
Results in Dunhuang



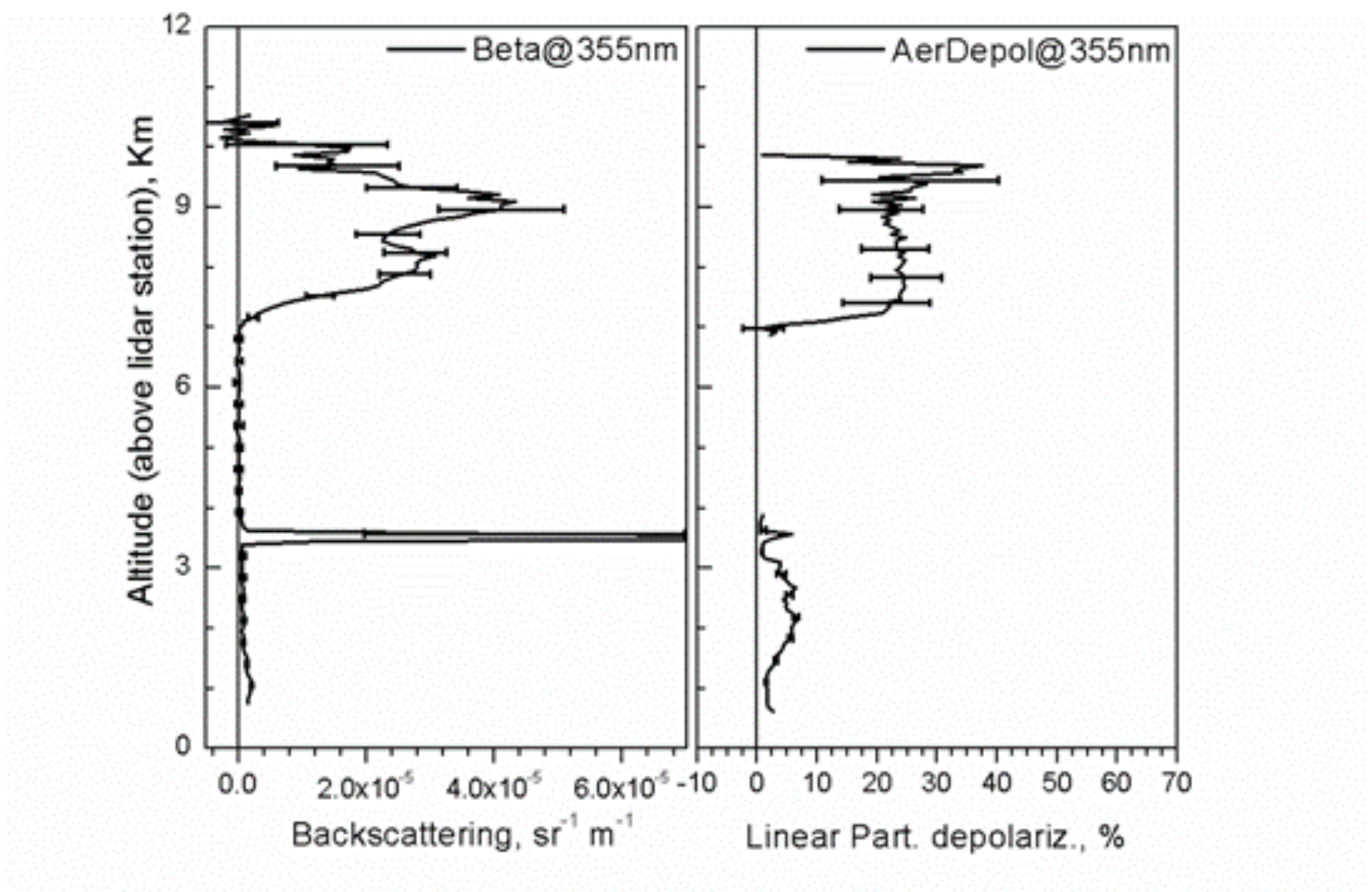
Results in Dunhuang

Water vapor mixing ratio

Dunhuang, Aug. 20, 2013



Results in Catania



Backscatter (left) and particle depolarization (right) profiles measure at Serra la Nave (Catania, Italy, 1760 m a.s.l.) (15min)

Conclusion

1. A new, versatile prototype of polarization, Raman scanning lidar system (named AMPLE - Aerosol Multi-wavelength Polarization LIDAR Experiment) has been designed and implemented.
2. Special, unusual design allow it to preform Raman measurements for high dense aerosol load thanks its high dynamic signal range.
3. Field measurement results show that AMPLE lidar system is suitable for quantity monitoring and 3D mapping of dense mineral aerosol, high polluted unban aerosol and volcanic ash plume.