8th AFWS

Atmospheric Monitoring for Air Fluorescence Observations in the TA experiment

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and the TA collaboration

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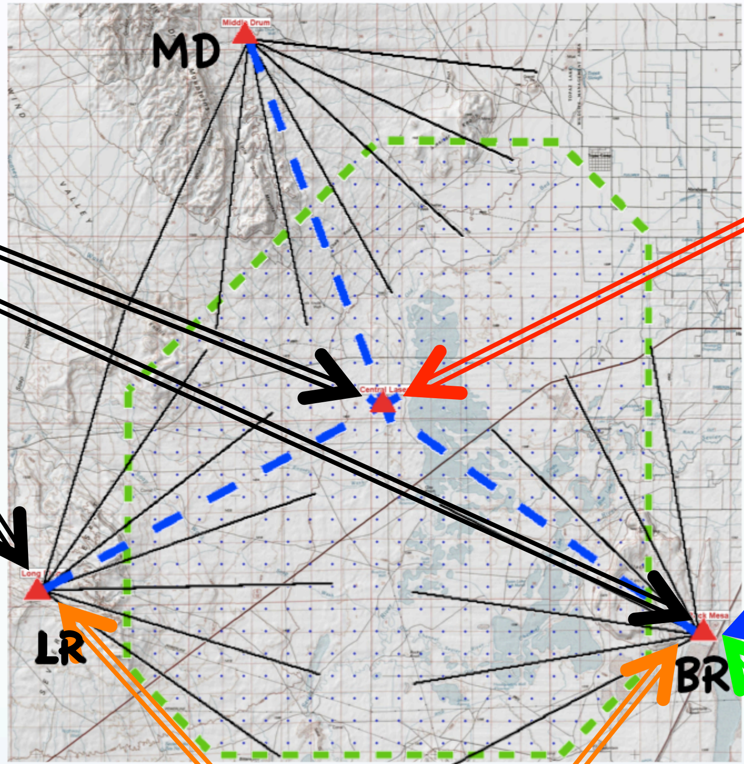
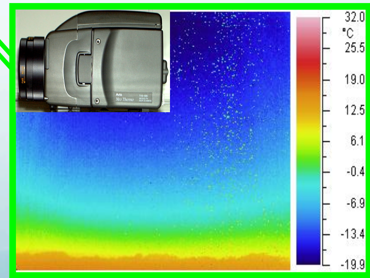
Atmospheric monitor in TA





- CLF
- LIDAR
- IR camera
- CCD camera
- weather monitor

Contents

- LIDAR observation

  The atmospheric transparency model of
  two kinds of altitude distribution was determined.

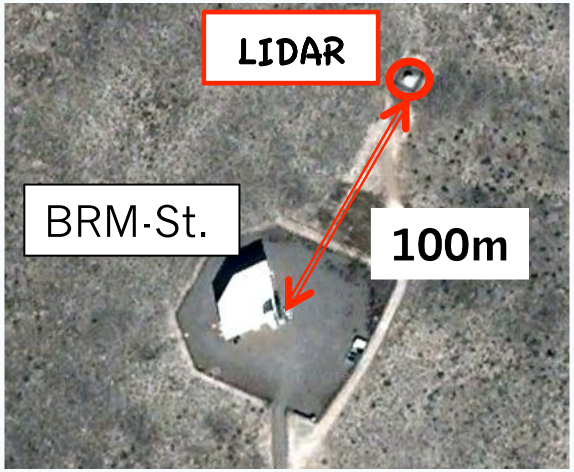
- Influence of using LIDAR's atmospheric transparency for FD reconstruction.

  FD reconstruct fluctuation was estimated
  by using the atmospheric model.
  ΔE= 11% , ΔX_{max}= 9g/cm^2 @19.5eV

- CLF Observation

  Correlated to the time variations was observed
  when compared to the CLF and LIDAR by Optical Depth.

LIDAR System



BRM Station

Telescope & dome of TA LIDAR

Measurement : Before and After FD observation

Slope	Horisontal shots - high power - 500 shots		$\alpha_M(h=0km)$
Klett's	Vertical shots	- high/low power - 500 shots	$\alpha_M(h=2\sim 8km)$
	Incline shots	- high power - 500 shots	$\alpha_M(h=0.5\sim 4km)$

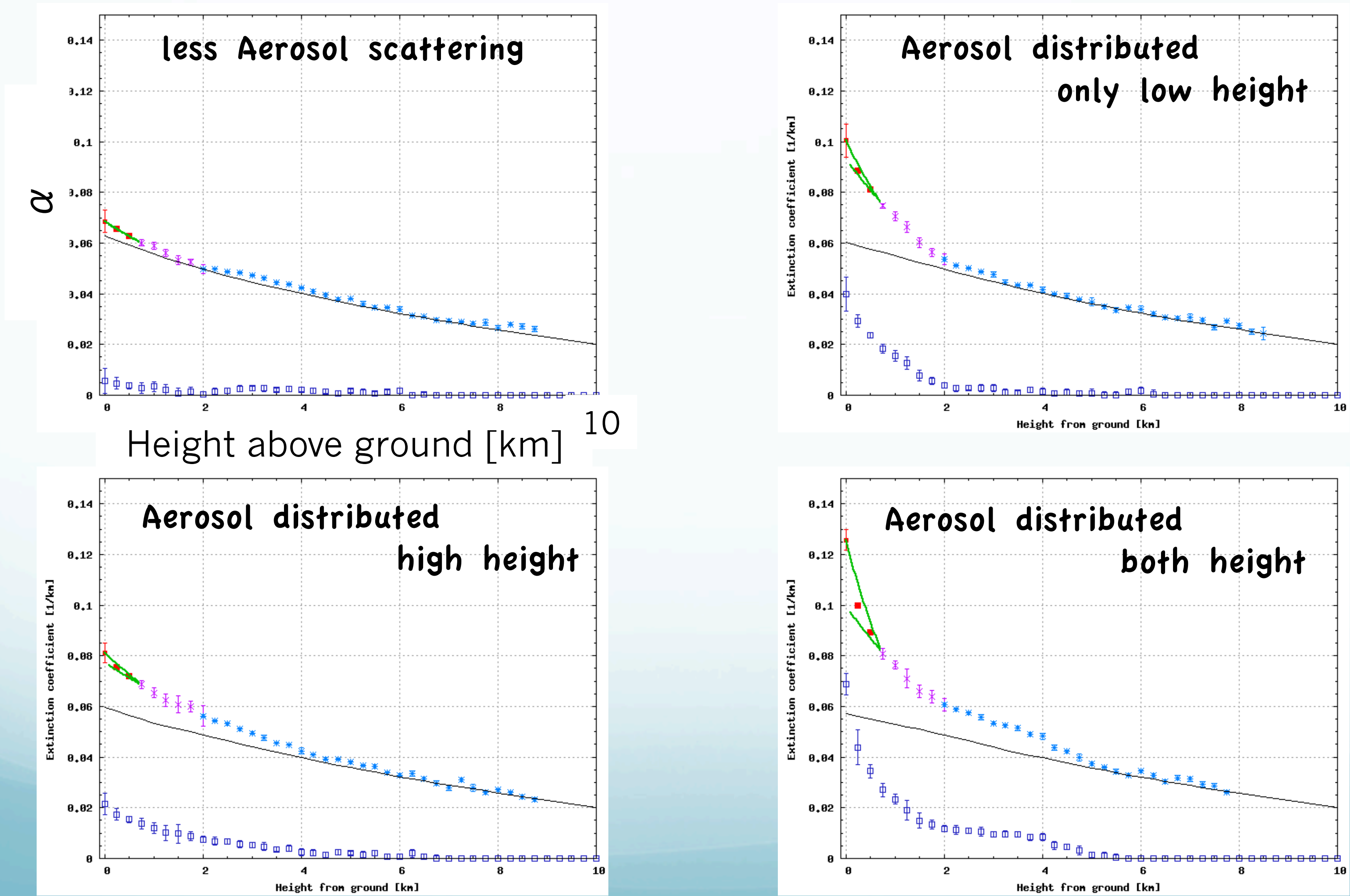
Data condition for determination atmospheric model

Data period	**~2 year (Sep.2007 ~ Oct.2009)**	
Using data	**Fine data**	**✓Good LIDAR observation** **✓Transparent atmosphere**
Rayleigh	**Radiosonde atmosphere @ELKO**	

Typicals of Extinction Coefficient

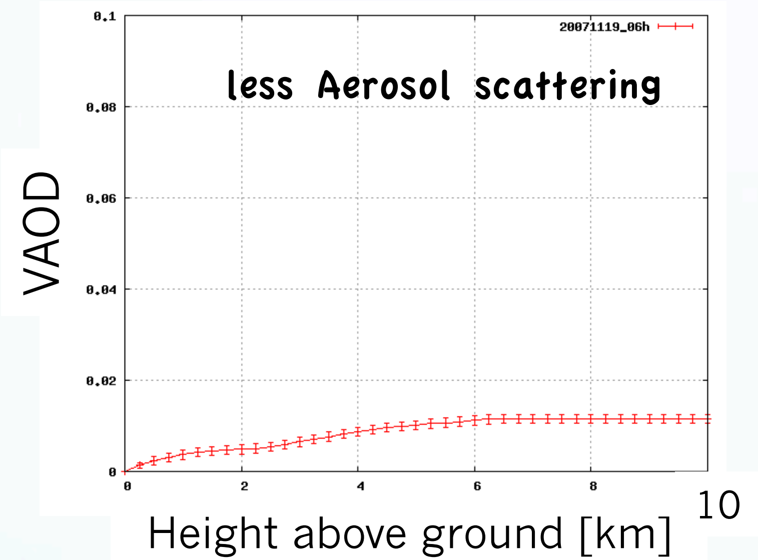
$$Np = Np_0 \exp(-\alpha x)$$

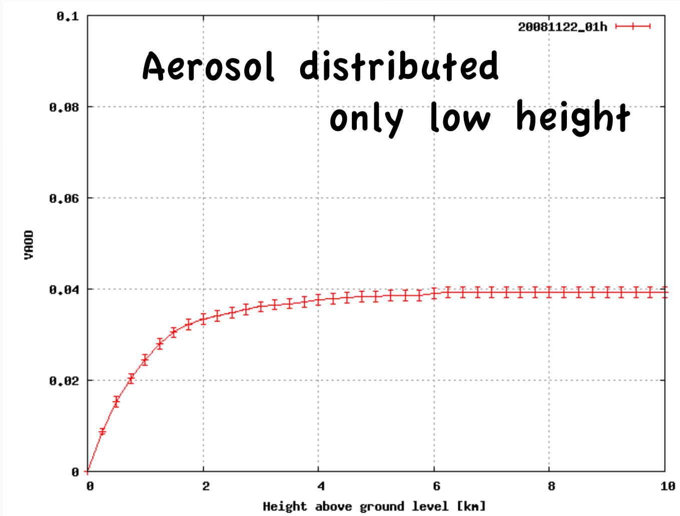
$$\alpha_{AS} = \alpha_{obs} - \alpha_{Rayleigh}$$

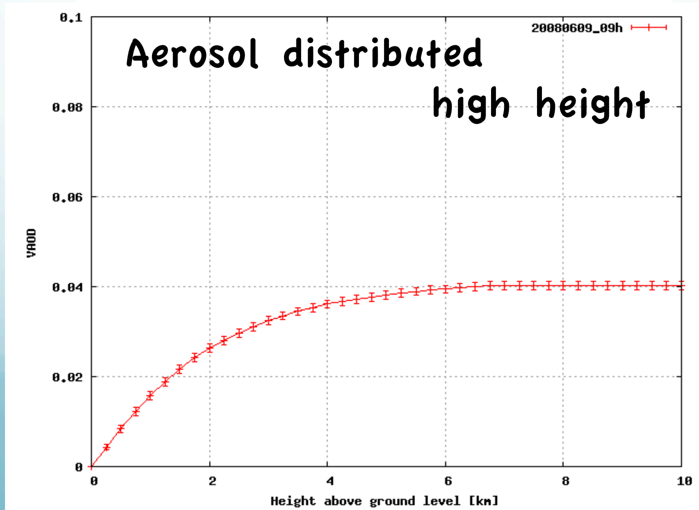


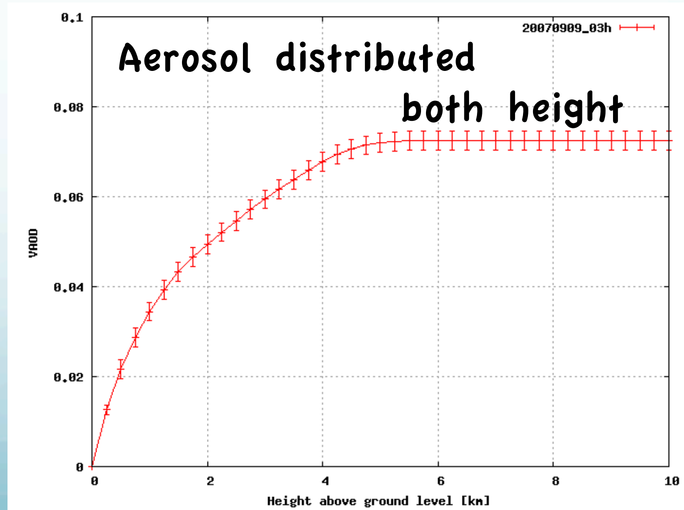
Typicals of VAOD

$$\alpha_{AS} = \alpha_{obs} - \alpha_{Rayleigh} \longrightarrow VAOD(h) = \int_0^h \alpha_{AS}(h)dh$$

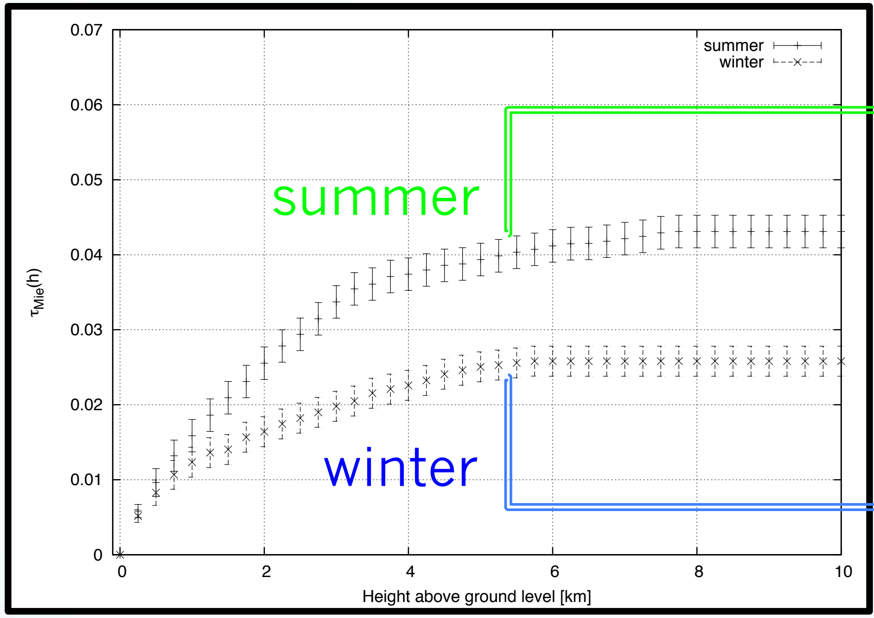




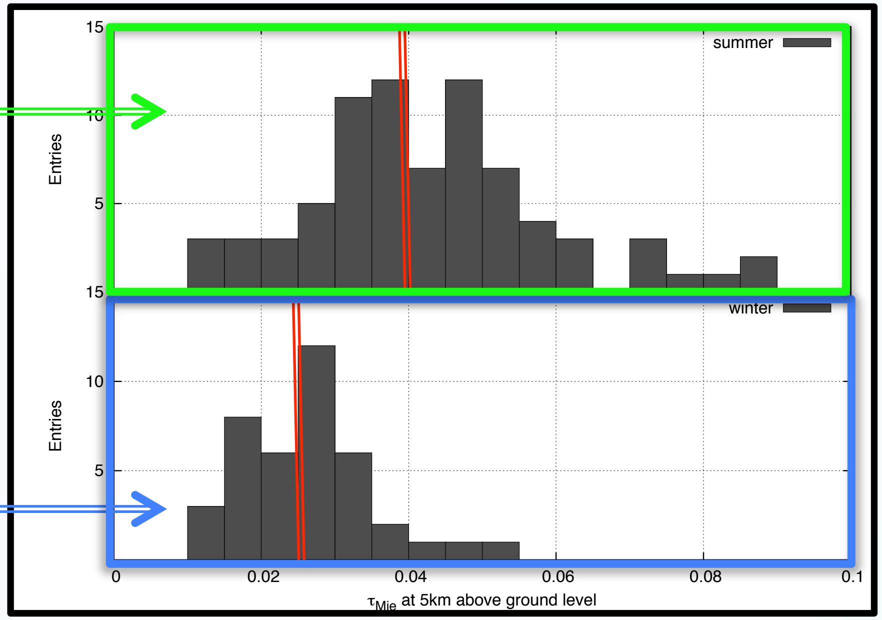




Seasonally Aerosol scattering



Median of VAOD for different seasons



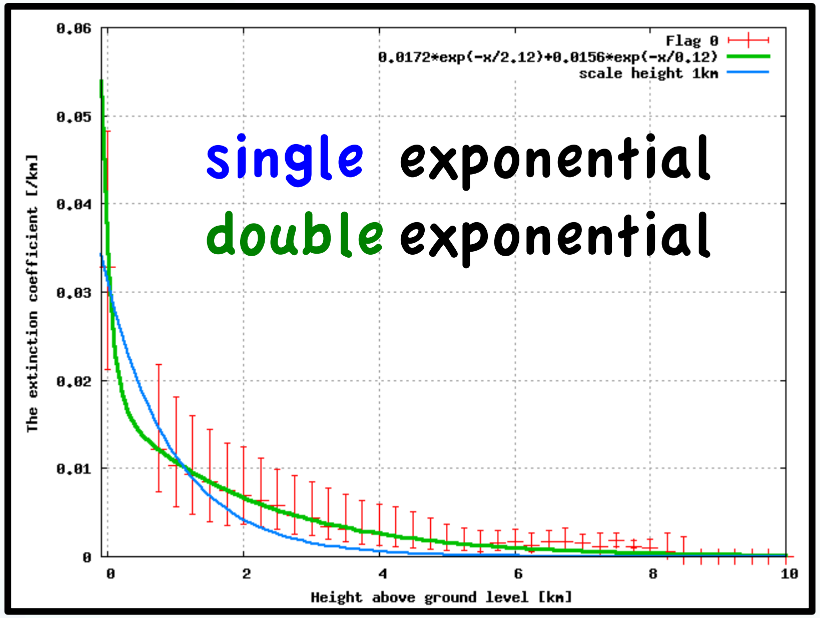
Distribution of VAOD at 5km above ground level for different seasons

Summer: **0.039** $^{+0.020}_{-0.012}$

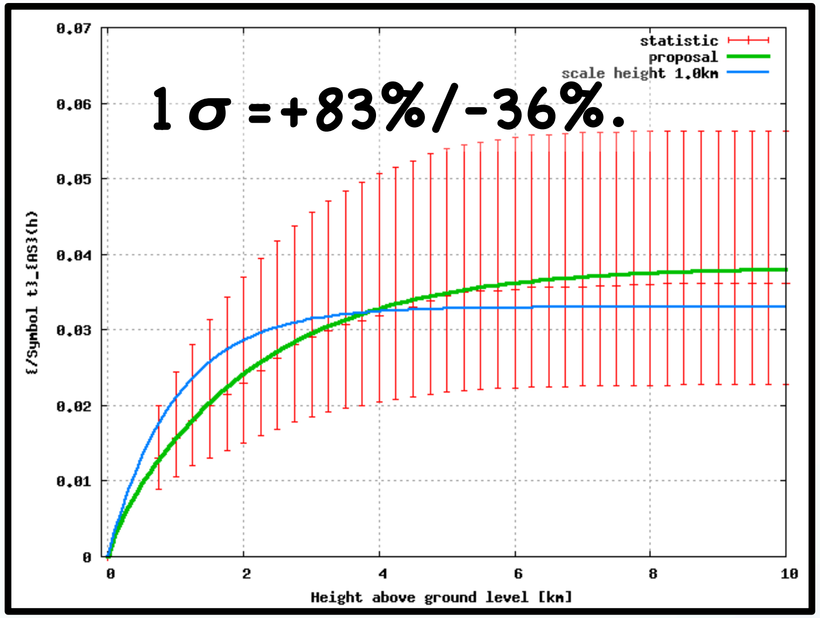
Winter : **0.025** $^{+0.010}_{-0.007}$

The effect of the aerosol component in summer is 1.5 times greater than that in winter.

Models of Atmospheric transparency



Extinction coefficient at each height



VAOD at each height

Double exponential Model

$$\alpha_{AS} = 0.019 \times \exp(-h/0.19) + 0.021 \times \exp(-h/2.1)$$

Single exponential Model

$$\alpha'_{AS} = 0.04 \times \exp(-h/0.9)$$

Fluctuation of FD reconstruction using atmospheric transparency by the **LIDAR** measurement.

Method

- MC simulation using daily atmospheric transparency to create a shower data.
- Simulated data are reconstructed using daily atmospheric transparency or model function.
- Estimating the impact of using a model function to compare the results with the reconstruction of each atmospheric transparency.
- ΔE is evaluated by the ratio, ΔX_{Max} will be evaluated by difference.

$$\frac{\Delta E}{E_{Daily}} = \frac{E_{Model} - E_{Daily}}{E_{Daily}}$$

$$\Delta X\max = X\max_{Model} - X\max_{Daily}$$

Simulation conditions

- Primary energy : logE= 18.5, 19.0 and 19.5 eV
- Direction: Zenith is between 0 ~ 60 ◦ (the isotropic)

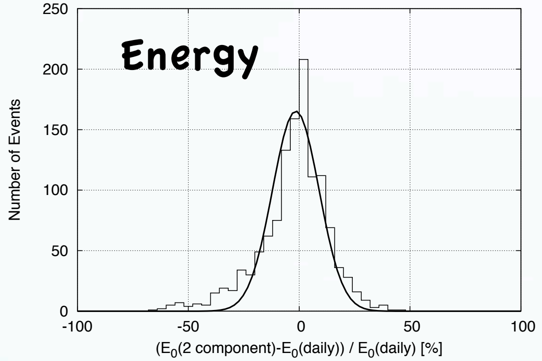
  Azimuth is between 0 ~ 360 ◦ (the isotropic)
- Core position : within 25 km of the CLF (center of TA FDs).
- Number of event : 20 events at each energy for each of 136 good LIDAR runs.
- Quality Cuts : Reconstructed X_{max} in field of view of FD.

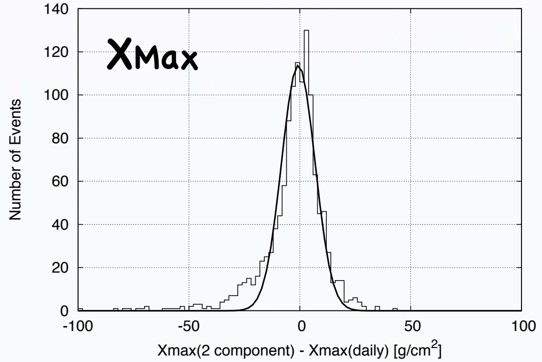
Reconstruction using

Daily atmospheric data or two atmospheric **models**

Fluctuations by using the atmospheric model

Daily vs model func. @logE=19.5 eV





$$\frac{\Delta E}{E_{Daily}} = \frac{E_{Model} - E_{Daily}}{E_{Daily}}$$

$$\Delta X\max = X\max_{Model} - X\max_{Daily}$$

Comparison of reconstructed fluctuation in atmospheric model.

E_0[eV]	#eve.	Atmos.	ΔE_0[%]	ΔX_{Max}[g/cm^2]
$10^{18.5}$	501	1 exp.	1.7± 6.4	4.6±7.1
	502	2 exp.	-2.4±6.3	-3.6±8.8
$10^{19.0}$	917	1 exp.	1.3±8.6	4.5±7.7
	919	2 exp.	-4.2±8.6	-5.0±8.6
$10^{19.5}$	1200	1 exp.	1.4±11.1	4.9±9.3
	1210	2 exp.	-0.6±10.6	0.2±7.6

The fluctuation not containing the reconstruction bias using atmospheric model at each energy

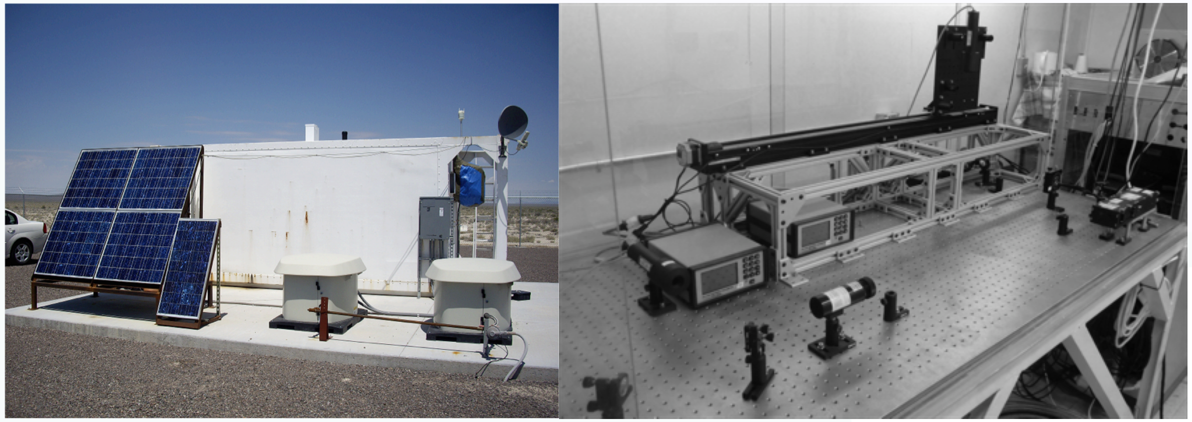
Rec. ΔE : 6%@18.5
9%@19.0
11%@19.5

Rec. ΔXmax : 9g@18.5
9g@19.0
9g@19.5

Conclusion

- The extinction coefficient α is obtained from LIDAR observation, then the VAOD $\tau_{AS}(h)$ is defined as the integration of α from the ground to height h.
- A model of α_{AS} with altitude was found by fitting two years of LIDAR observations.
- The range of variation of the daily data from the model is +83%/-36%.
- When an $10^{19.5}$ eV air shower is reconstructed using the model function, the systematic uncertainty of energy is shown to be about 11%.
- And the systematic uncertainty of X_{Max} to be about 9 g/cm^2 by comparing MC simulation data.

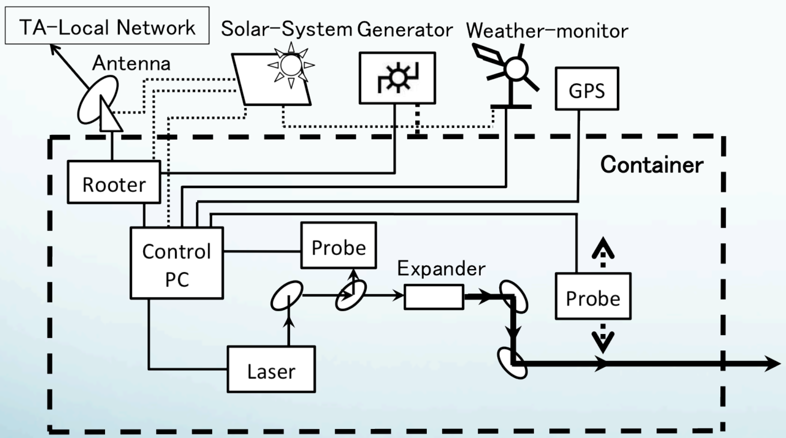
CLF System



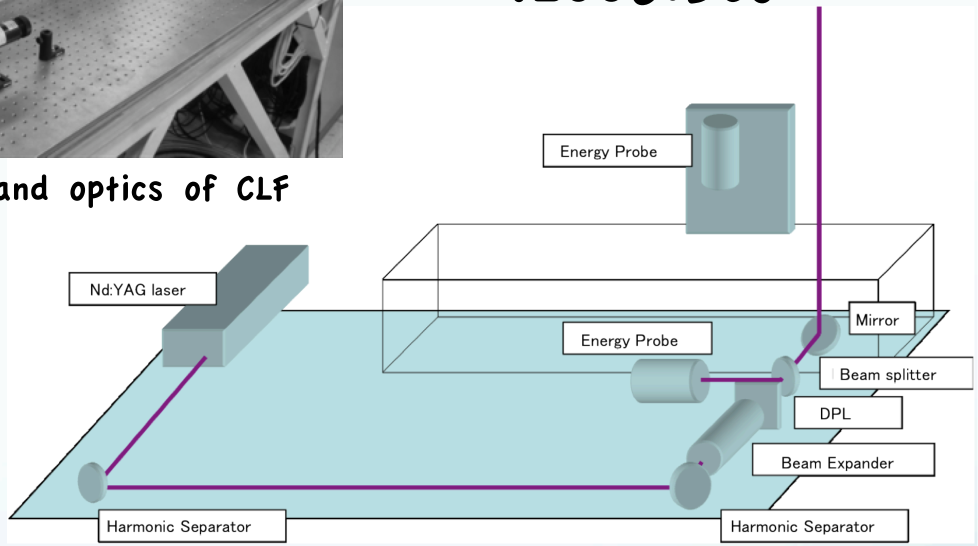
CLF container and power generation system and optics of CLF

Starting CLF operation

:2008.Dec～



Block diagram of devices for CLF



Optical diagram of the CLF

CLF laser is injected into FD's FOV

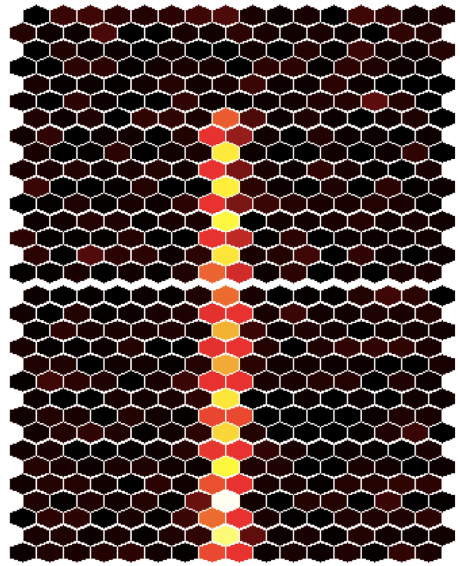
:300 times

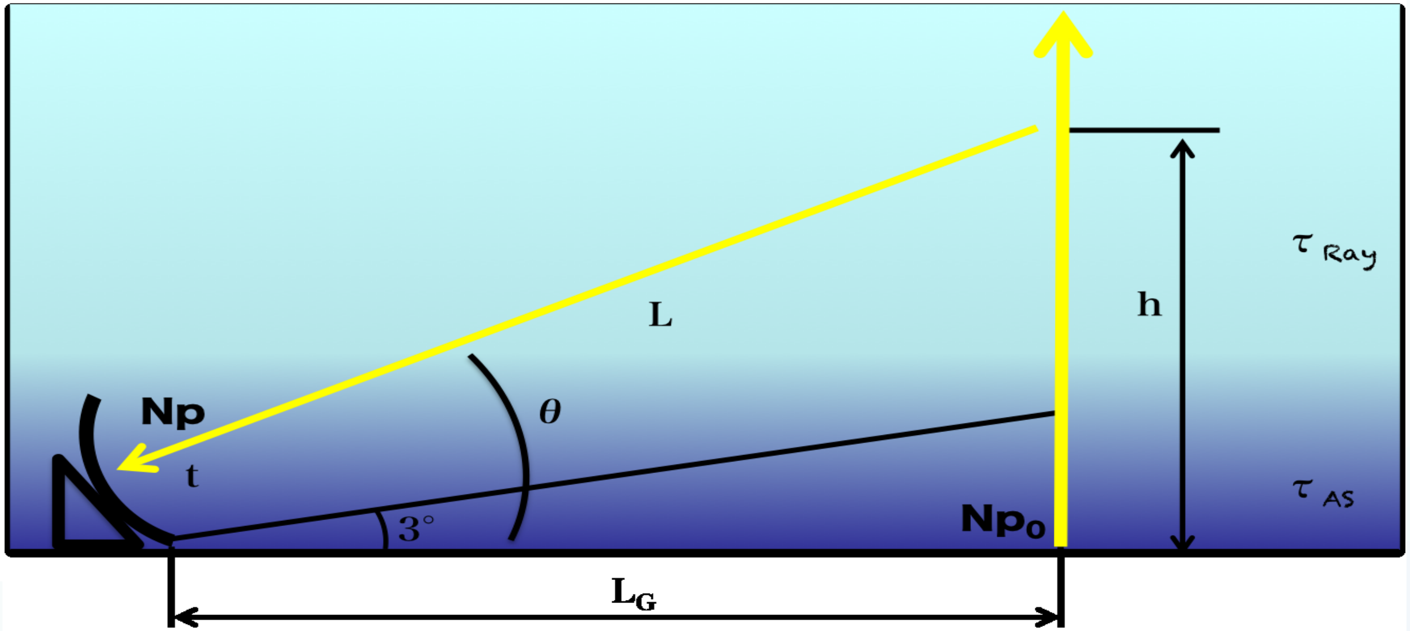
:10Hz

:vertical direction

:every 30 minutes.

CLF's observation image





VAOD eq.

$$Np = Np_0 C f_{(\phi)} e^{-(\alpha_M + \alpha_A)(L_1 + L_2)} \Big/ {L_2}^2$$

$$\begin{cases} T_{ij} = e^{-\tau_i / \sin\theta_j} \equiv e^{-\alpha_i L_j} \\ L_j = h / \sin\theta_j, \tau_i \equiv \alpha_i h \end{cases}$$

$$Np = Np_0 T_{Ray} T_{AS} (S_{Ray} + S_{AS}) T'_{Ray} T'_{AS}$$

analysis method

$$Np = Np_0 T_{Ray} T_{AS} (S_{Ray} + S_{AS}) T'_{Ray} T'_{AS}$$

$$\exp\left(-(\alpha_{Ray} + \alpha_{AS})\Delta h\right)\left(\frac{\sigma_{Ray}\alpha_{Ray} + \sigma_{AS}\alpha_{AS}}{\alpha_{Ray} + \alpha_{AS}}\right)$$

$$Np_{ideal} = Np_{i0} T_{Ray} S_{Ray} T'_{Ray}$$

Uniform atmospheric

$$T = \exp(-\tau(h))$$

$$T' = \exp(-\tau(h)/\sin\theta)$$

$$Np \big/ Np_{idea} = \frac{E}{E_i} T_{AS} T'_{AS} \left(1 + S_{AS} \big/ S_{Ray}\right)$$

$$Np \big/ Np_{idea} = \frac{E}{E_i} \exp\left(-\frac{1+\sin\theta}{\sin\theta}\tau_{AS}(h)\right)\left(1 + S_{AS} \big/ S_{Ray}\right)$$

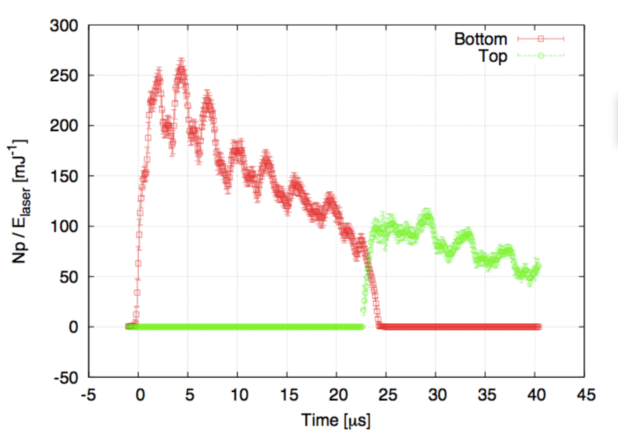
No aerosols

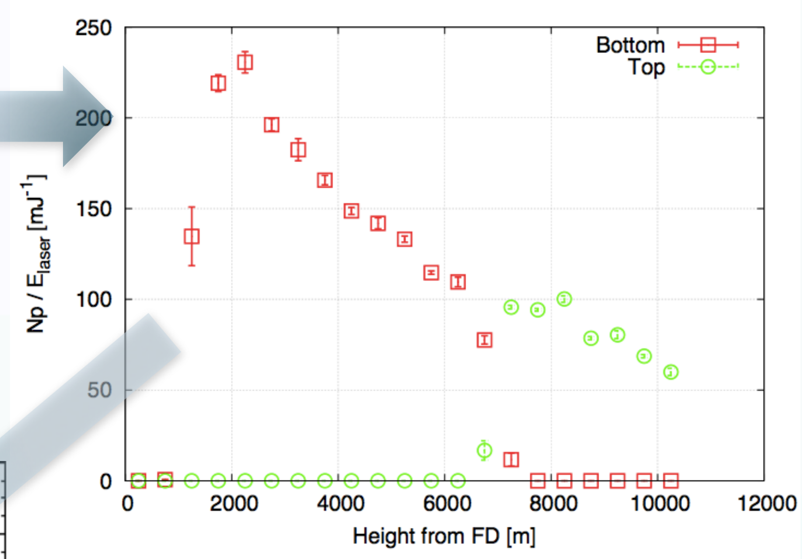
$$h > 7km$$

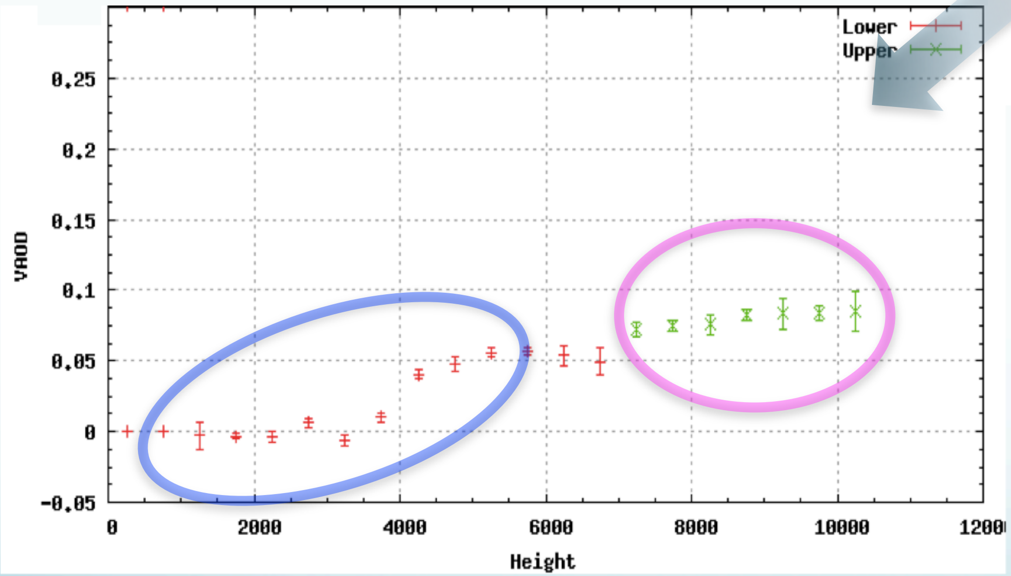
$$\alpha_{AS} = 0[km^{-1}]$$

$$\frac{\frac{Np}{E}}{\frac{Np_{ideal}}{E_i}} = \exp\left(-\frac{1+\sin\theta}{\sin\theta}\tau_{AS}(h)\right)$$

Example



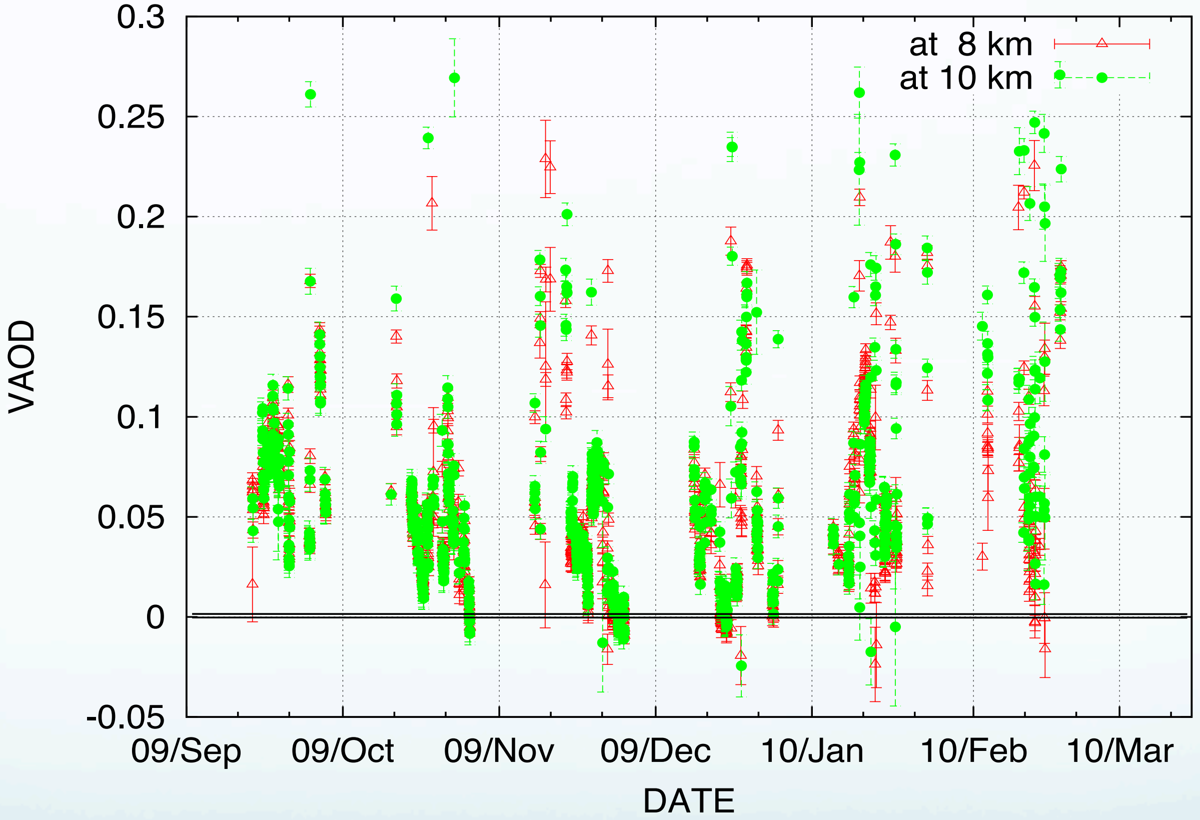




An analysis steady because the scattered source of high view is only an atmospheric molecule is possible.

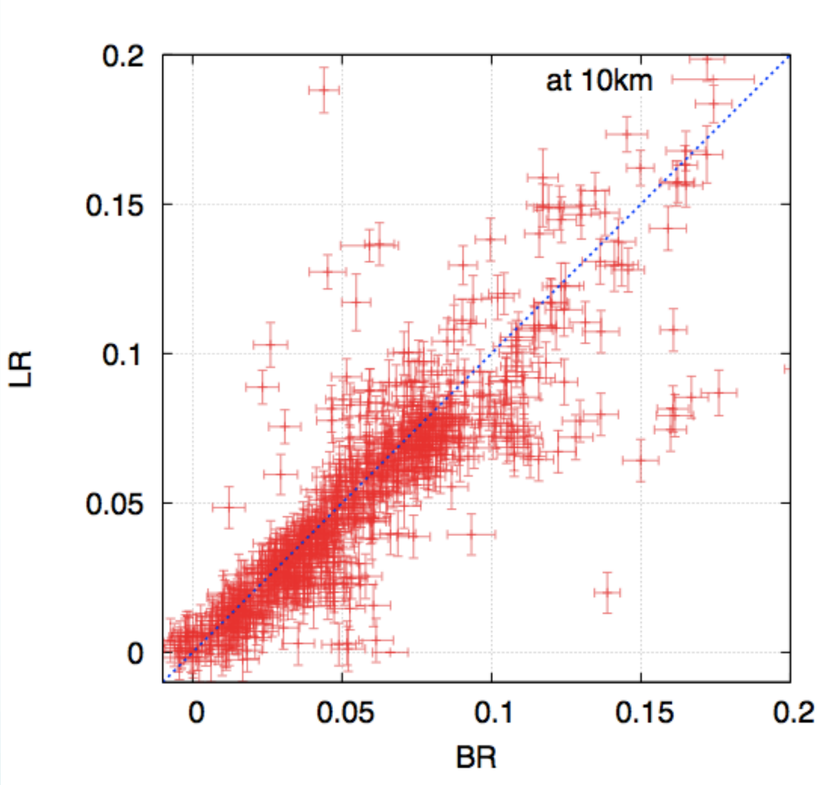
It is necessary to understand cross-section "$\sigma(\theta)$" for the VAOD analysis at low altitude which highly influence by the aerosol.

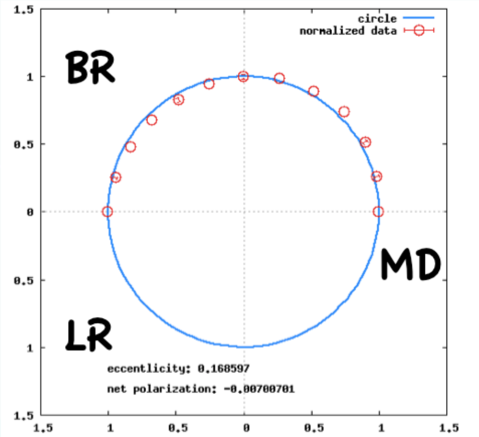
Date variation of VAOD
@8km & 10km

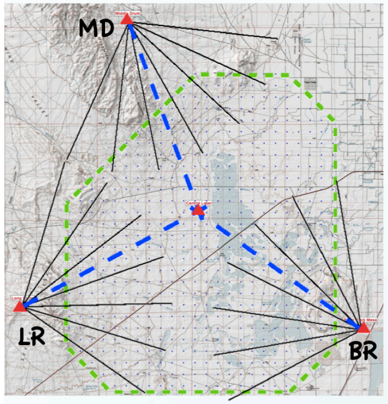


- Winter atmosphere may be clear.
- There is correlation with LIDAR.

Comparison between BR and LR
(2009.08.26～2010.02.14)





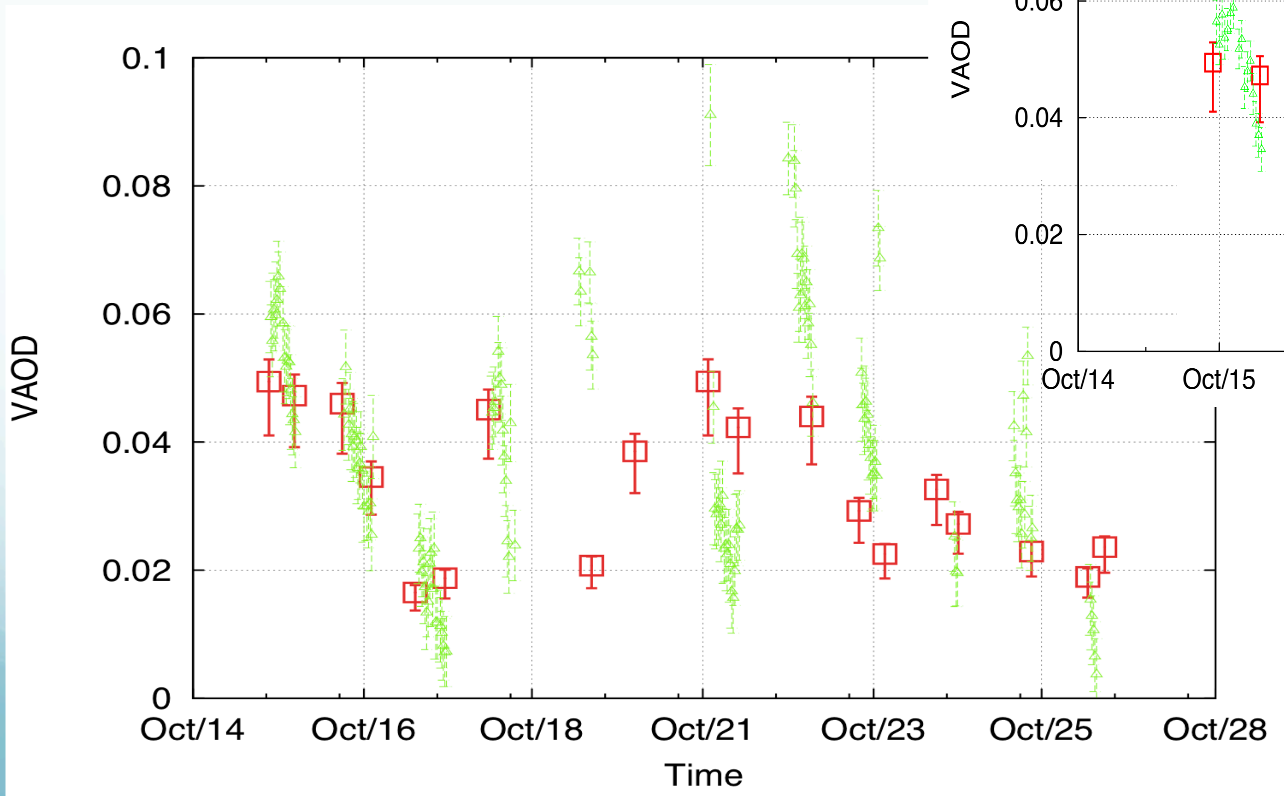


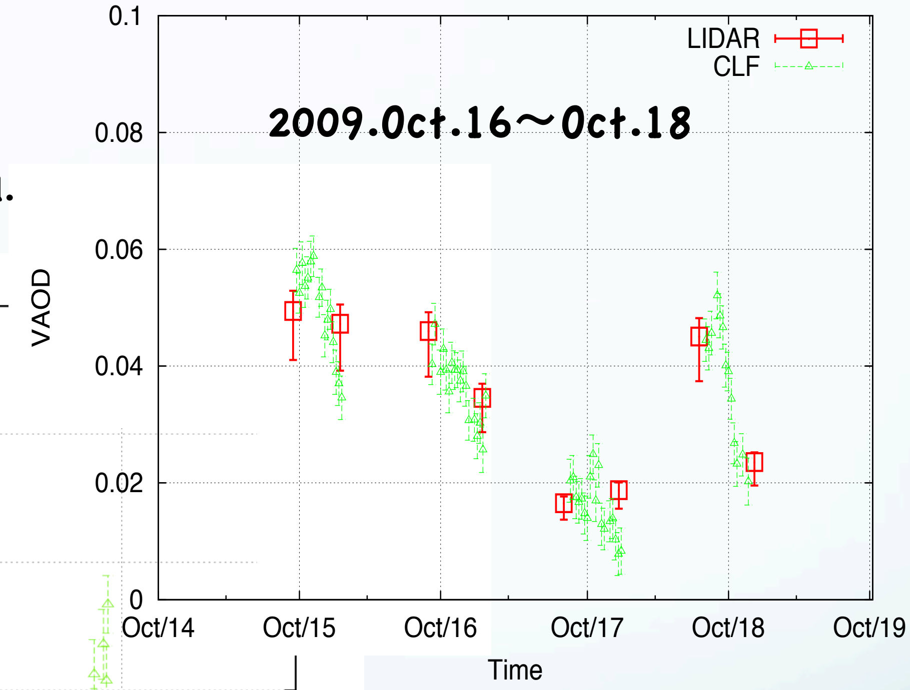
- VAOD of LR is slightly larger than BR.
- The adjustment of de-polarization was shifted slightly in this observation term.
- The likely influence of de-polarization adjustment.
- For future, I will confirm in another observation term.

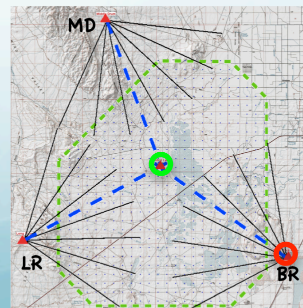
Comparison of time dependence between LIDAR and CLF

✓LIDAR can be measured VAOD to LIDAR from the cloud.

✓CLF can measure VAOD until over the cloud, because CLF laser penetrate the cloud.







Conclusion

- VAOD was analyzed by using the CLF event of high view camera's.
- BR and LR are consistent with a few %.
- There is a correlation VAOD measured in each of the CLF and LIDAR.
- Using the CLF, will be able to interpolate for the atmospheric transparency of the period where have not been observed by LIDAR.

For the future

LIDAR@CLF system

Hardware (general drawing)

- Back-scatter detector is set up on top of the CLF.
- LIDAR@CLF use PMT of 20mm and 38mm in diameter.
- telescope & 20mm PMT for High altitude (1.5~7.0~ km)
- 38mm PMT for Low altitude (~2.5km)

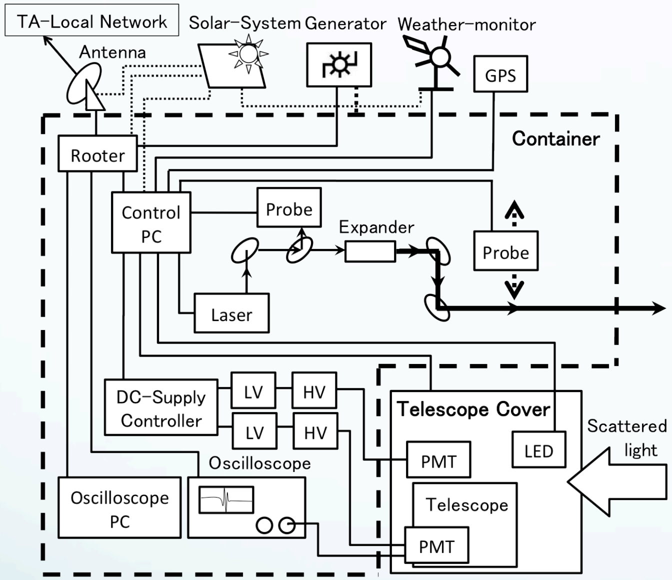


Fig. Block diagram of LIDAR@CLF

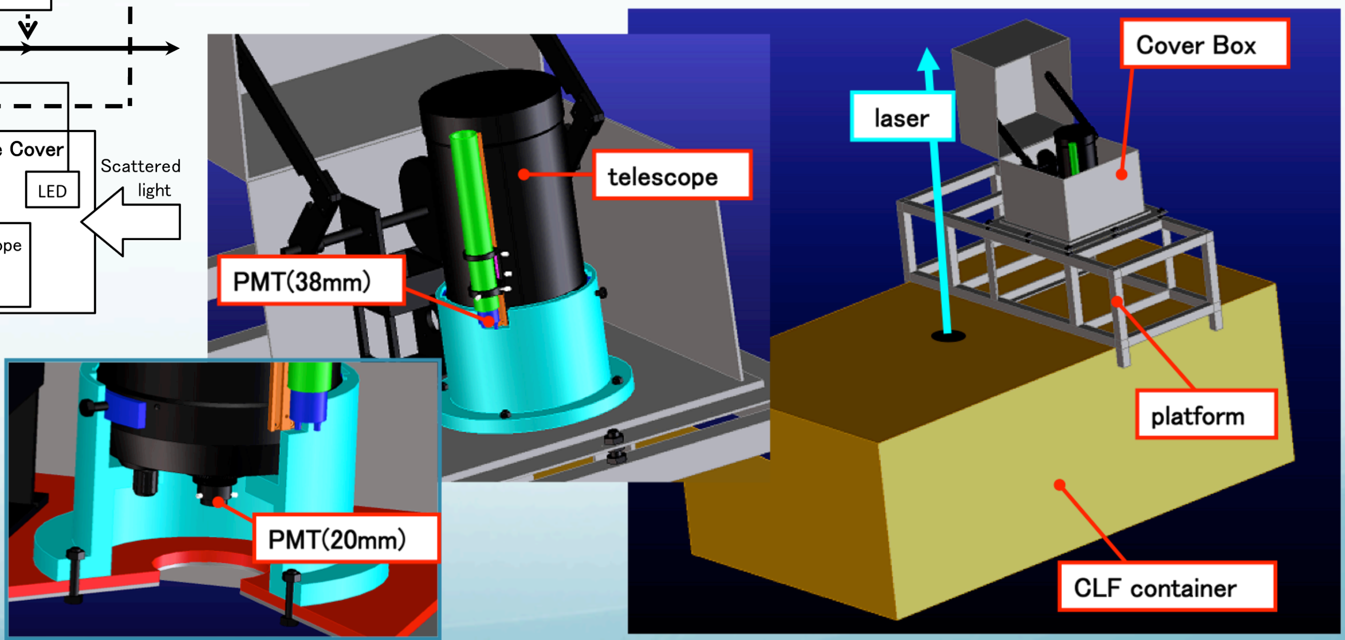
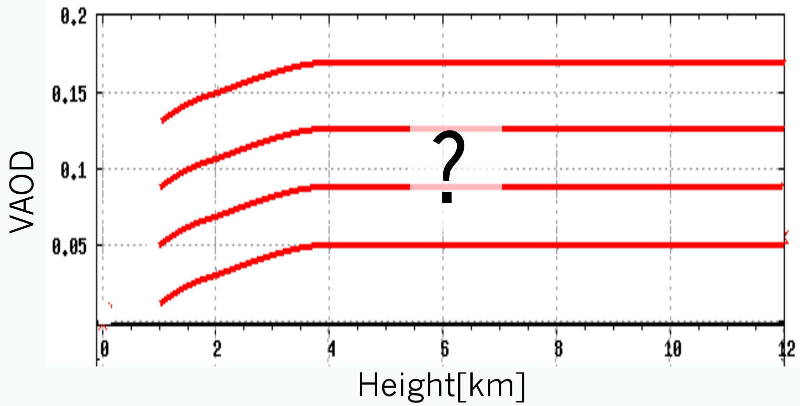


Fig. general drawing of LIDAR@CLF

Analysis policy of LIDAR@CLF

Analytical result only of LIDAR@CLF



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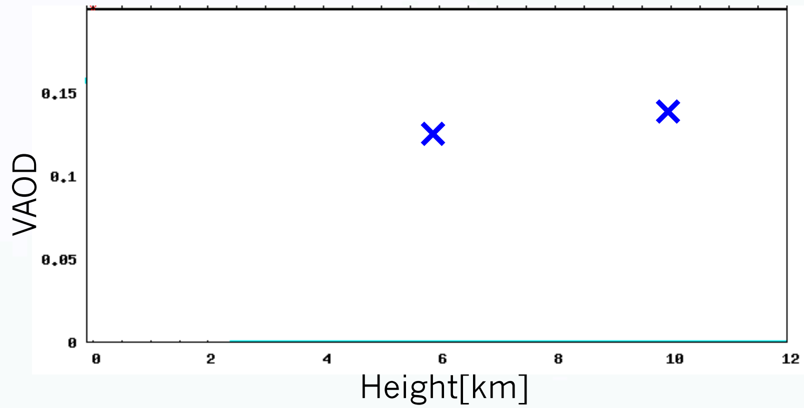
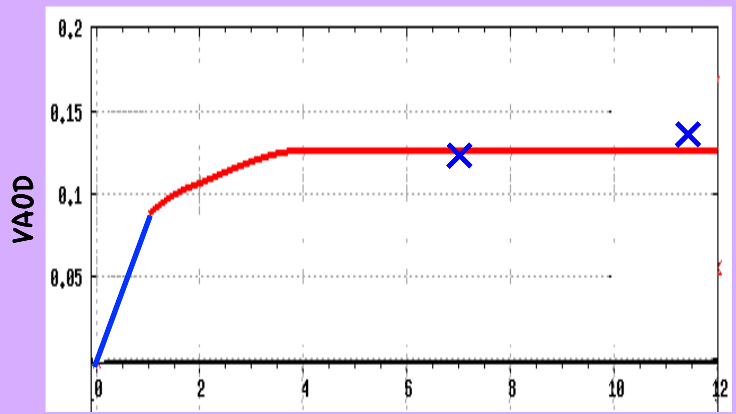
Analytical result only of CLF



Normalized by VAOD of CLF.



Analytical result of LIDAR@CLF and CLF

- Shape of VAOD according to height is determined from LIDAR@CLF.
- VAOD at high altitude is determined from the analysis of CLF.