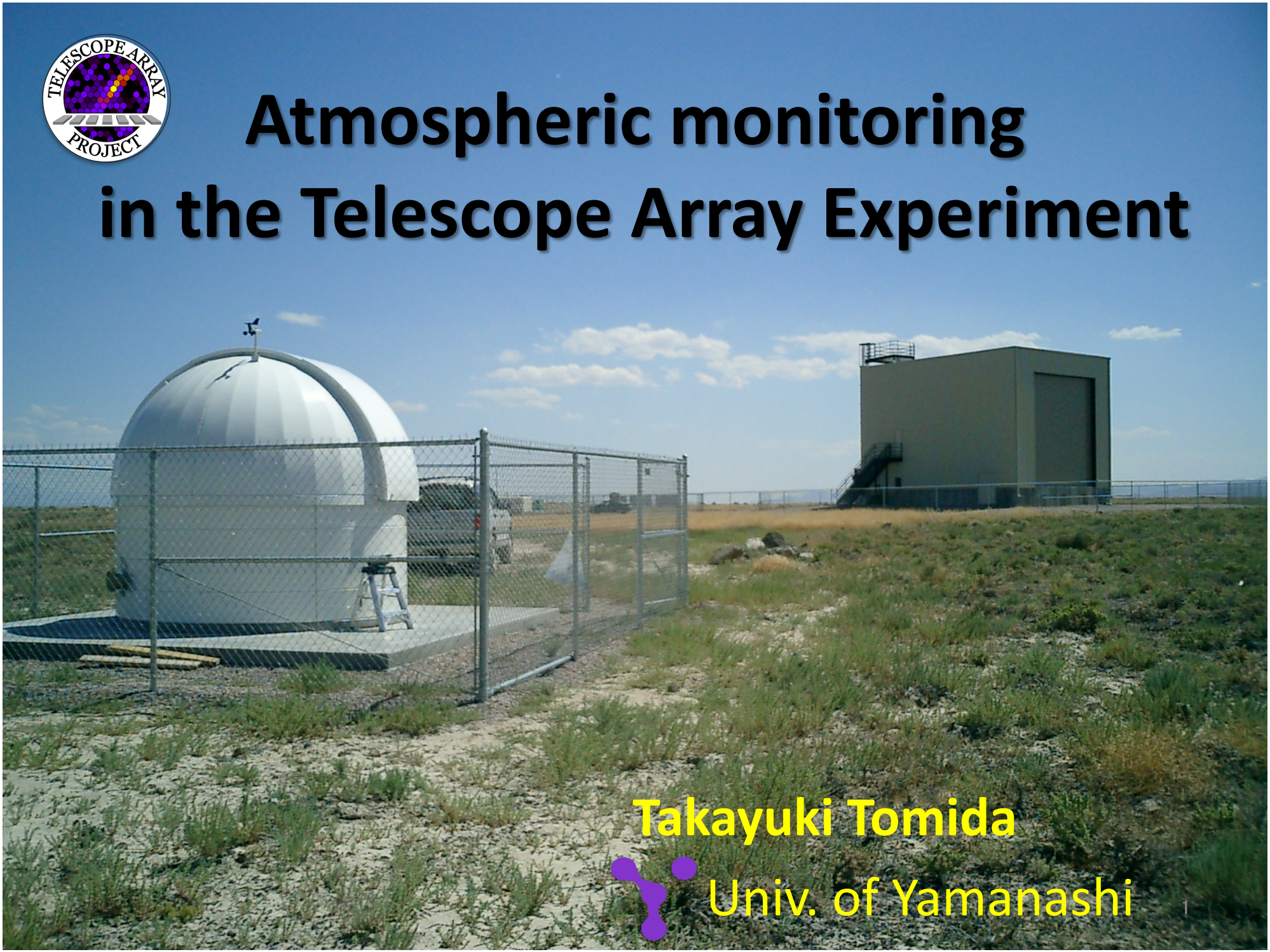
Atmospheric monitoring in the Telescope Array Experiment



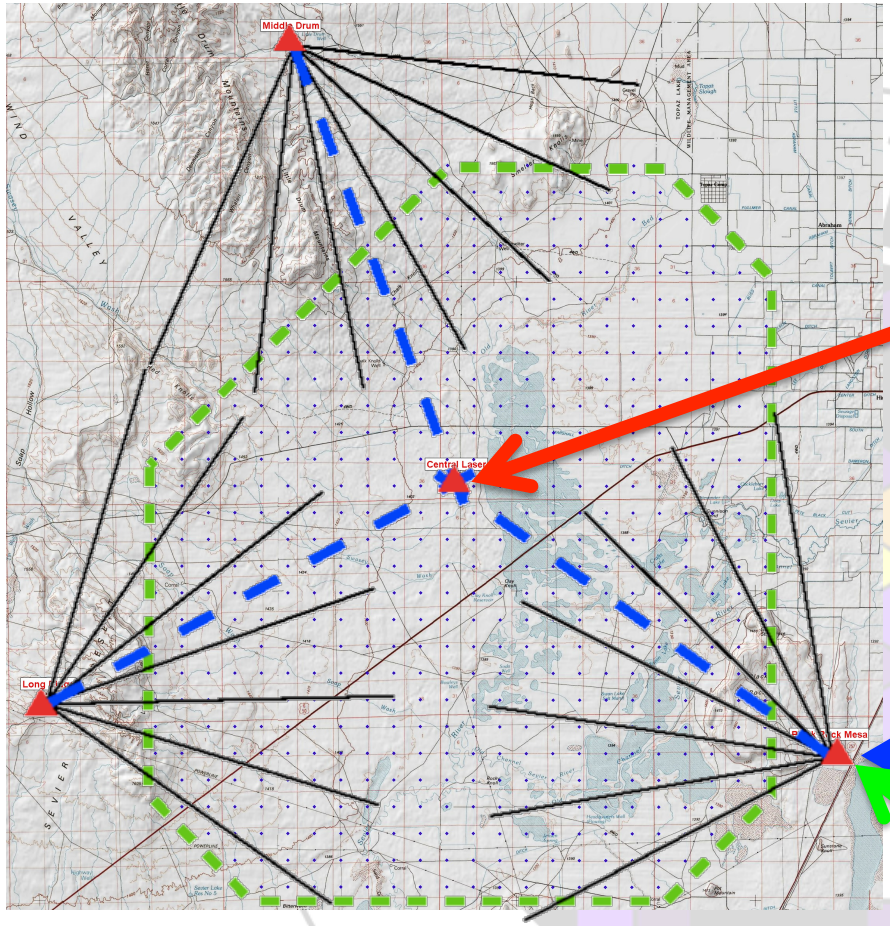
Takayuki Tomida

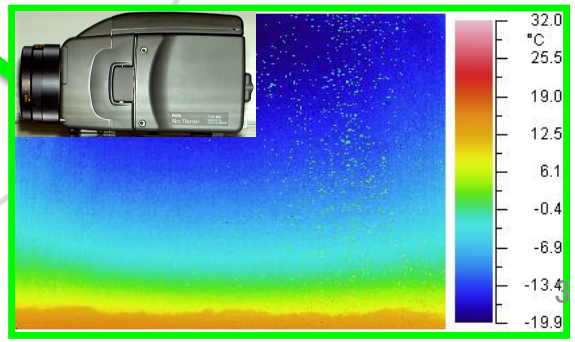
Univ. of Yamanashi

Contents

- Atmospheric monitoring devices in TA
- Atmospheric parameter from Radiosonde
- Atmospheric transparency from LIDAR
- Cloud monitor with IR camera
- For the future

Atmospheric monitoring devices in TA





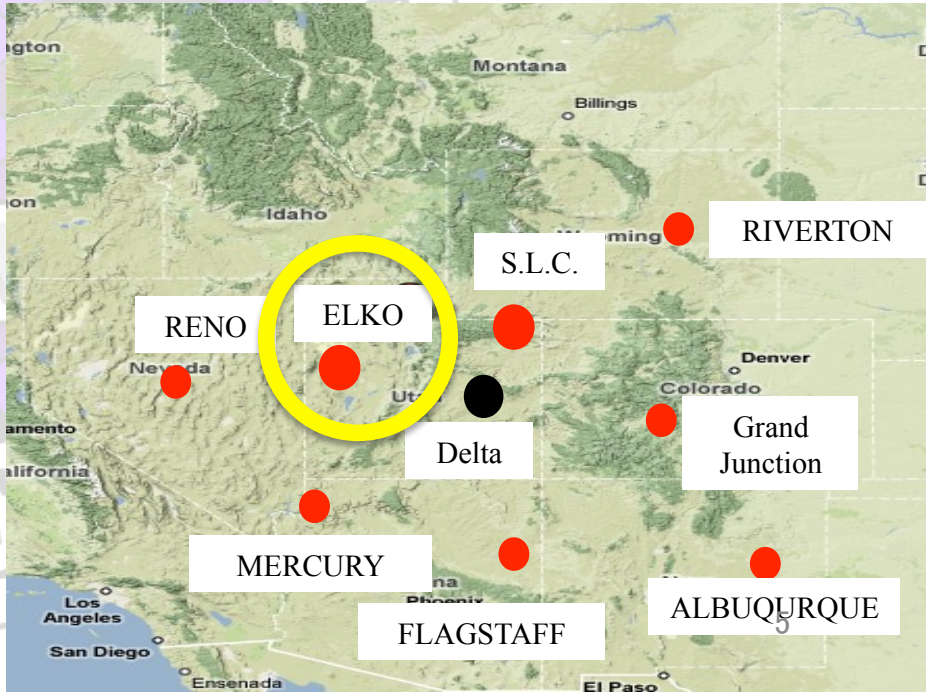
- CLF
- LIDAR
- IR camera
- weather monitor

Atmospheric parameter from Radiosonde

Atmospheric parameter from Radiosonde

- The data of radiosonde is used as an atmospheric parameter.
- The radiosonde is observed every 0 & 12 o'clock (UTC).

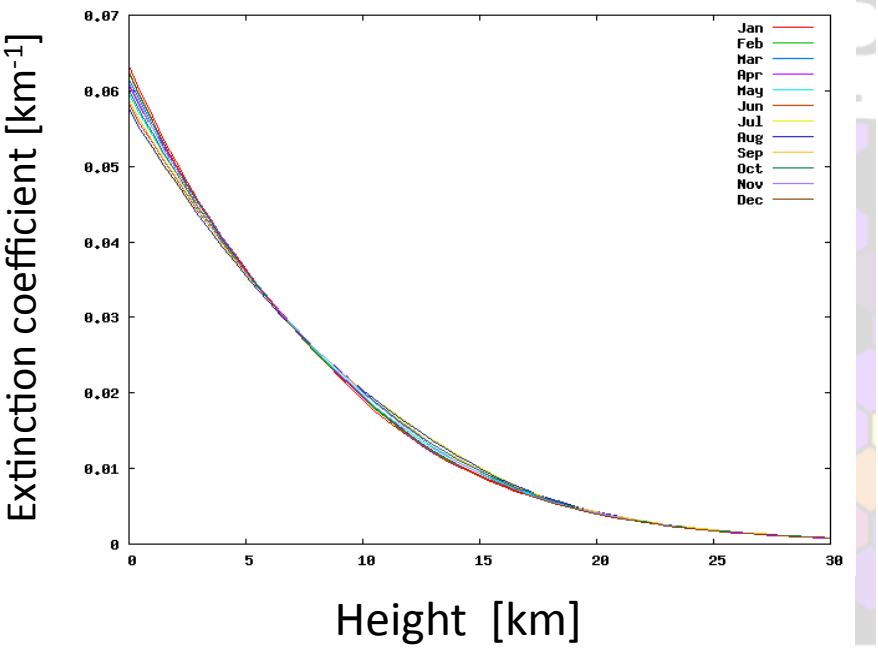
- The atmospheric parameter is monthly average of each observation time at ELKO



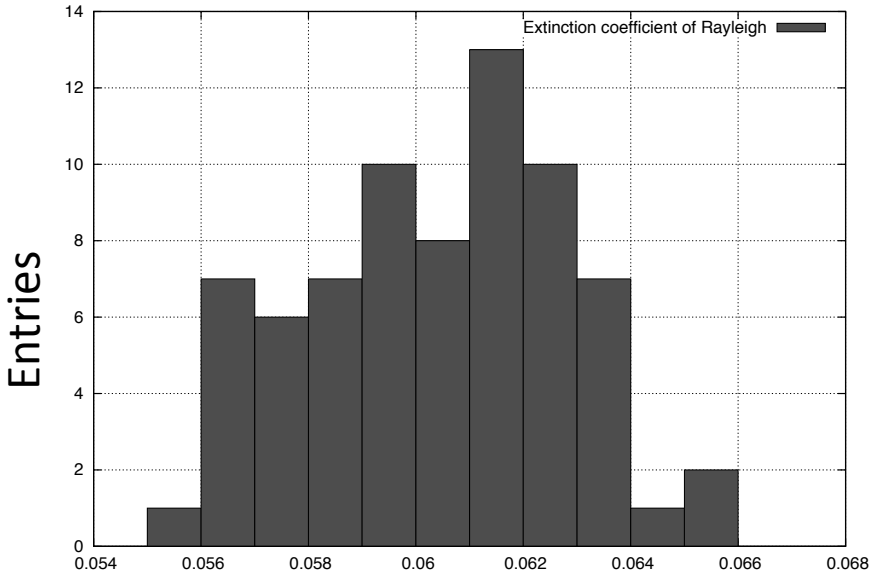
Extinction coefficient (α) of Rayleigh

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

Every month



Extinction coefficient of Rayleigh Scattering

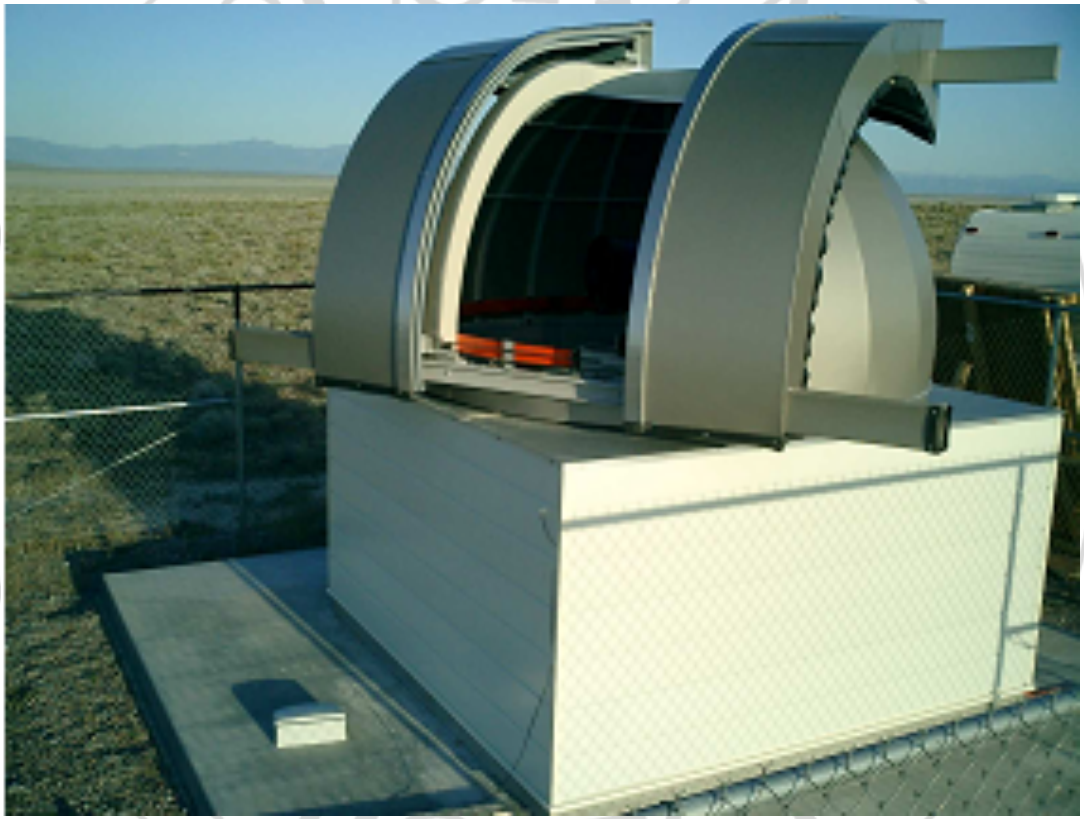


Distribution of Extinction Coefficient from Rayleigh scattering at Ground

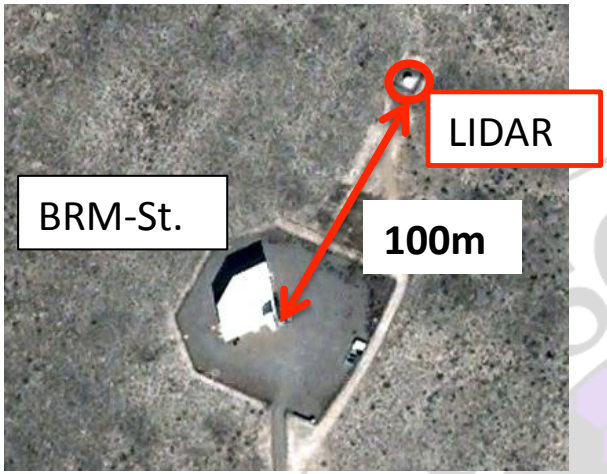
Median of α_{Ray} at ground level
0.060 ± 0.002 [km^-1]

Ref. :Anthony Bucholtz,Rayleigh-scattering calculations for the terrestrial atmosphere

Atmospheric Transparency from LIDAR



LIDAR System



BRM Station

Telescope & dome of TA LIDAR

Measurement : Before and After FD observation

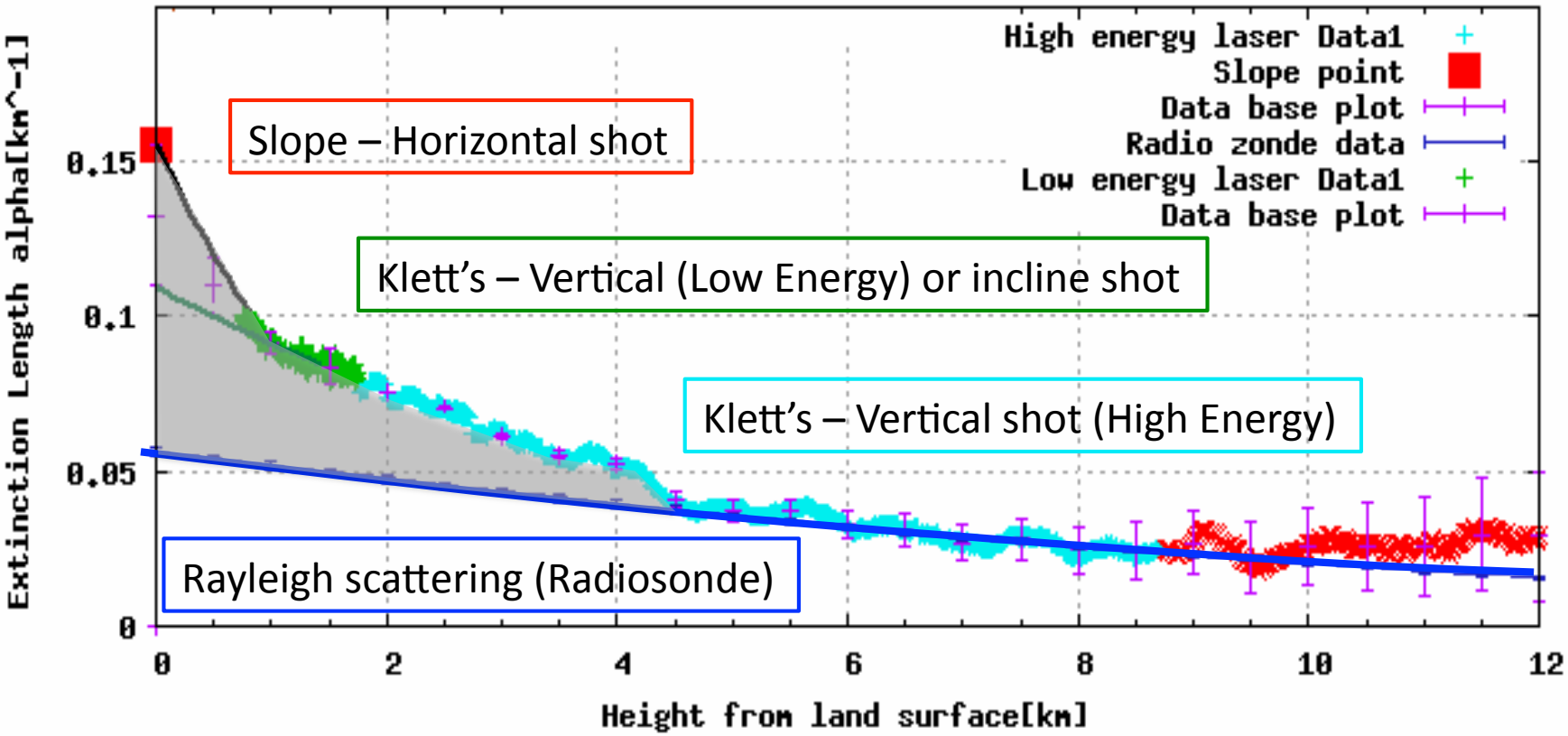
Slope	Horisontal shots - high power - 500 shots	$\alpha_M(h=0km)$
Klett's	Vertical shots - high/low power - 500 shots	$\alpha_M(h=2\sim8km)$ $\alpha_M(h=0.5\sim3km)$
	Incline shots - high power - 500 shots	$\alpha_M(h=0.5\sim4km)$

Data condition

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

Extinction coefficient (α) from LIDAR

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



The difference between α of observation and α of Rayleigh is α of aerosol.

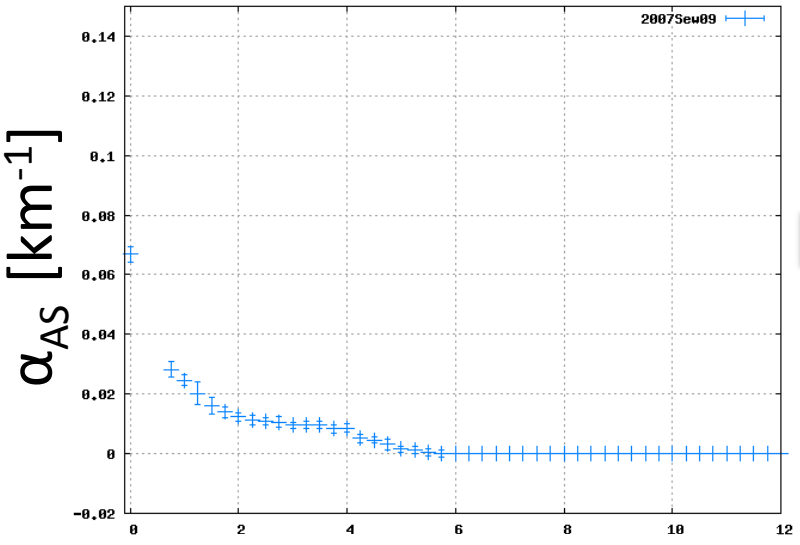
$$\alpha_{AS} = \alpha_{obs} - \alpha_{Rayleigh}$$

VAOD

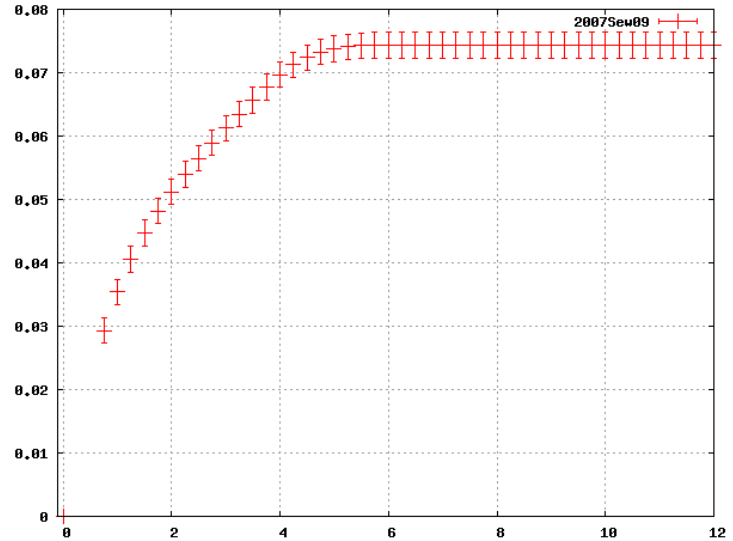
- VAOD (Vertical Aerosol Optical Depth) is an integration value of α of aerosol.

$$VAOD_{AS}(h) = \int_0^h \alpha_{AS}(h)dh$$

α_{AS} v.s. Height above ground

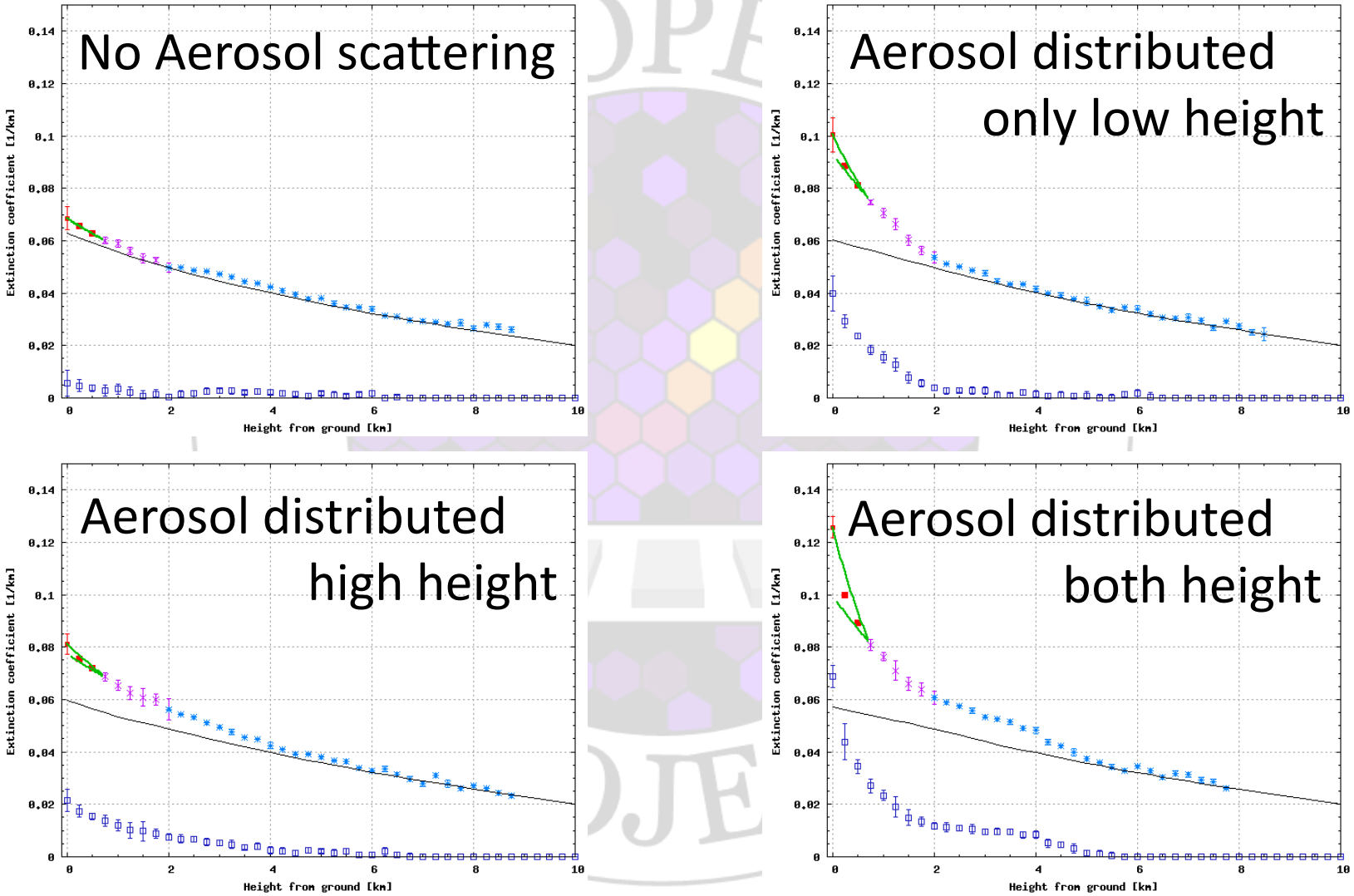


VAOD v.s. Height above ground



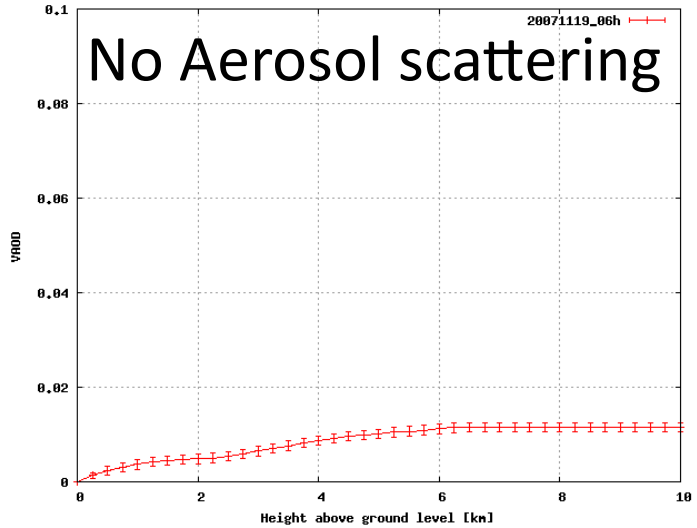
Typicals of Extinction Coefficient

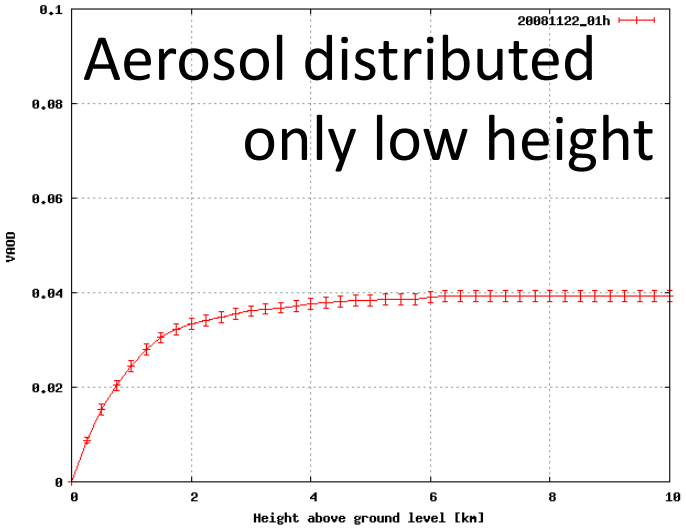
α v.s. Height above ground

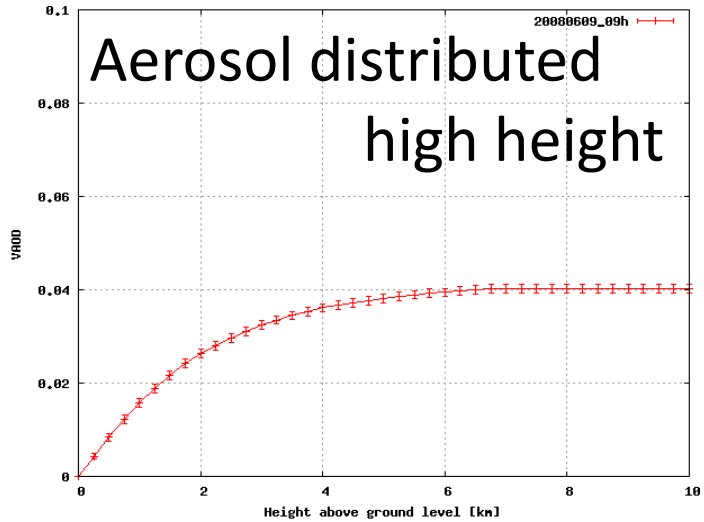


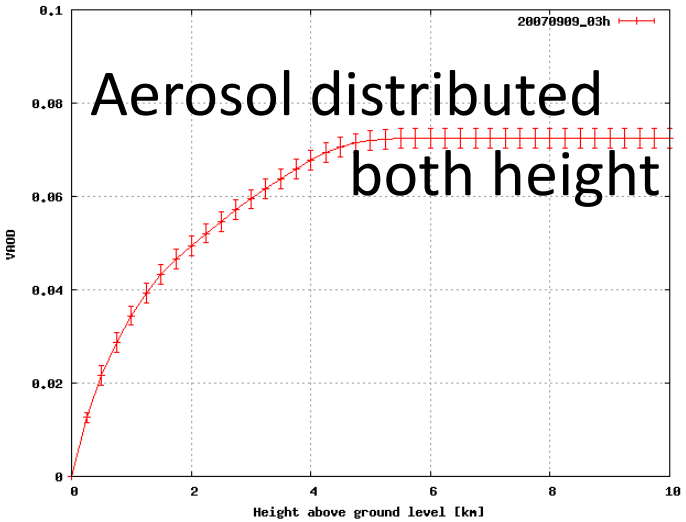
Typicals of VAOD

VAOD v.s. Height above ground









Determine Typical Transparency of aerosol

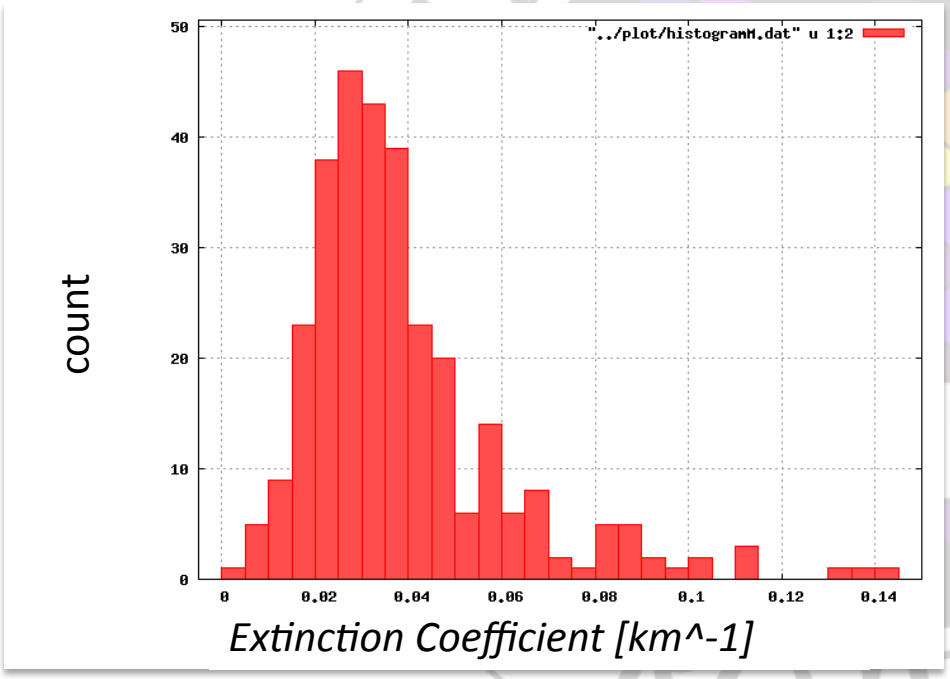
1. The typical α_{AS}(0km) is determined.
2. Scale Height of distribution is determined by VAOD(3.0～5.0km).

II

Hires Like

Determine Typical Transparency of aerosol

1. The typical α_{AS}(0km) is determined.
2. Scale Height of distribution is determined by VAOD(3.0～5.0km).



Median

$0.034 \pm {}^{0.015}_{0.013}$ [km^{-1}]

Horizontal Attenuation Length

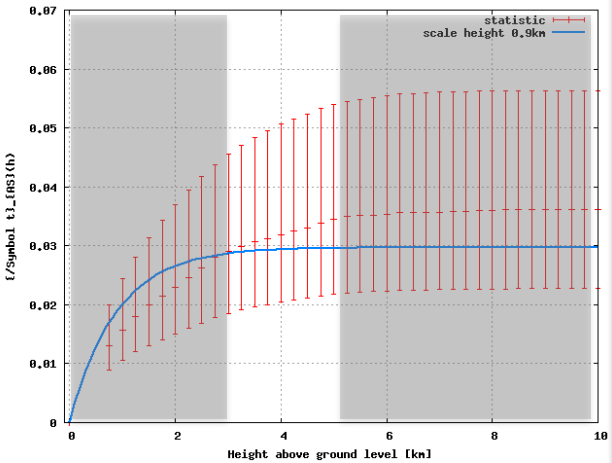
$29.4 \pm {}^{16}_{10}$ [km]

Distribution of Extinction Coefficient from aerosol scattering at Ground

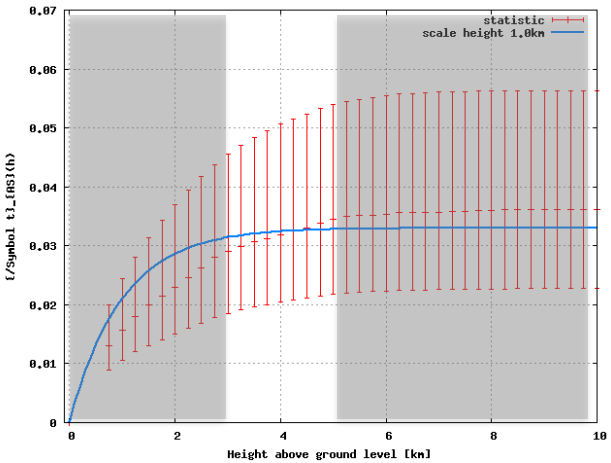
Determine Typical Transparency of aerosol

1. α_{AS}(0km) of the typical is determined.
2. Scale Height of distribution is determined by VAOD(3.0～5.0km).

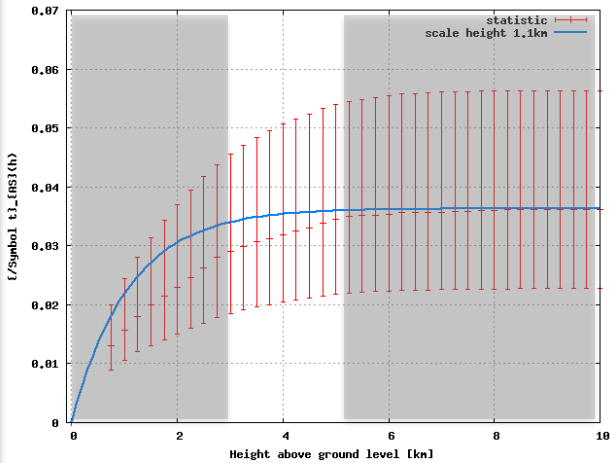
Scale height = 0.9km



Scale height = 1.0km



Scale height = 1.1km

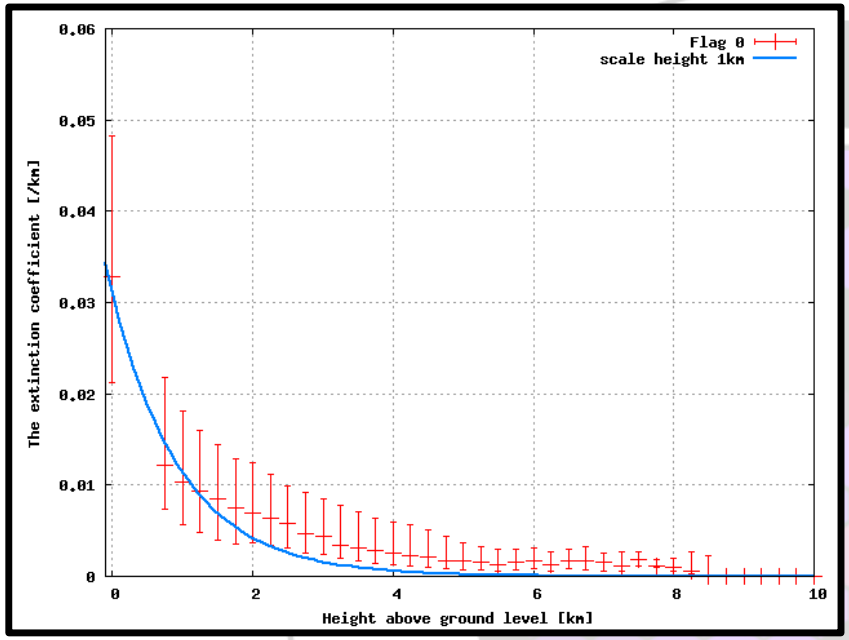


[Scale Height = 1.0 km] shows the Typical better than another height in the range (3.0～5.0km).

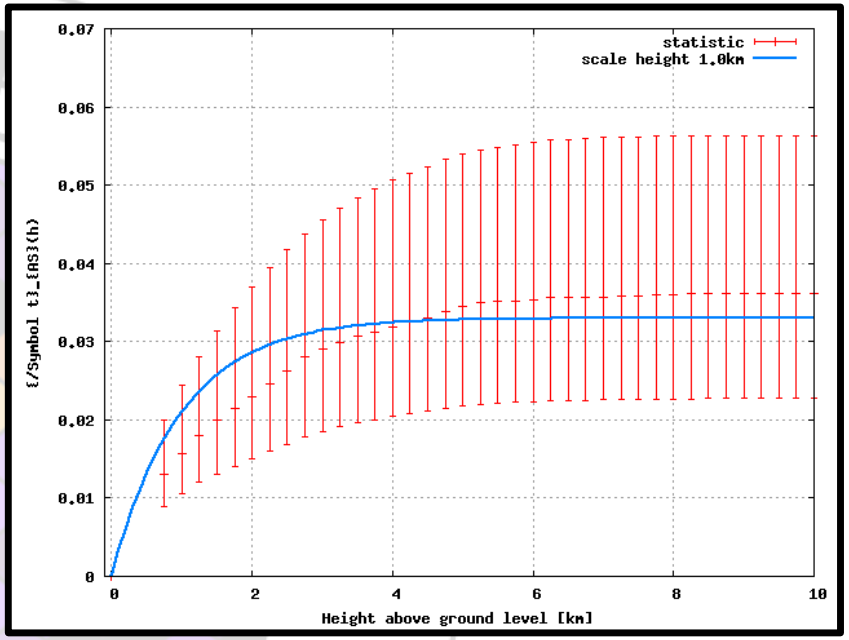
Typical of Transparency of aerosol

- Extinction Coefficient at ground :$0.034 \pm {}^{0.015}_{0.013}$ km^{-1}
- Attenuation Length at ground :$29.4 \pm {}^{16}_{10}$ km
- Scale Height :1km

Appearance of the atmosphere that Scale Height is 1 km



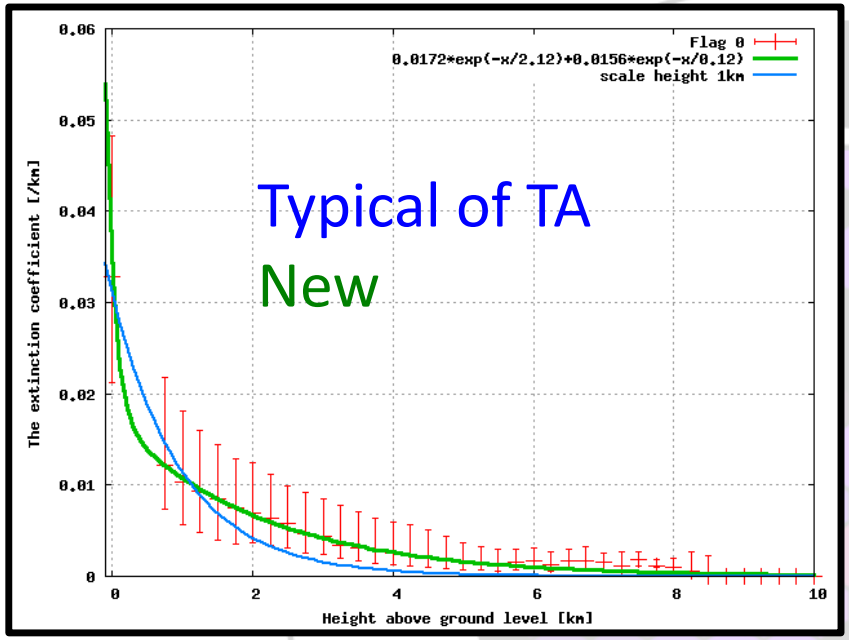
Extinction coefficient at each height



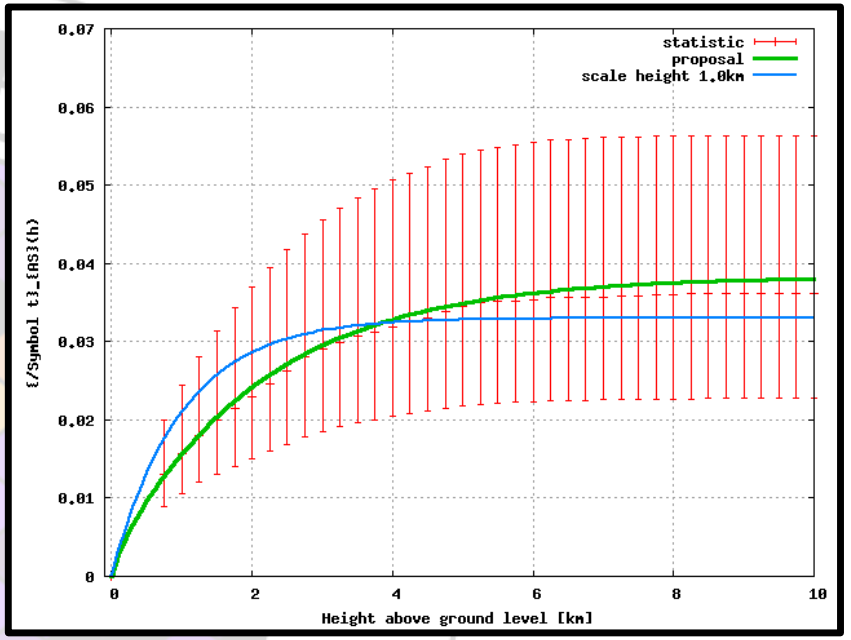
VAOD at each height

α of aerosol is estimated smaller than median at over 1.5km above ground. VAOD is estimated bigger than median at under 4.0km above ground.

Atmospheric typical (new)



Extinction coefficient at each height

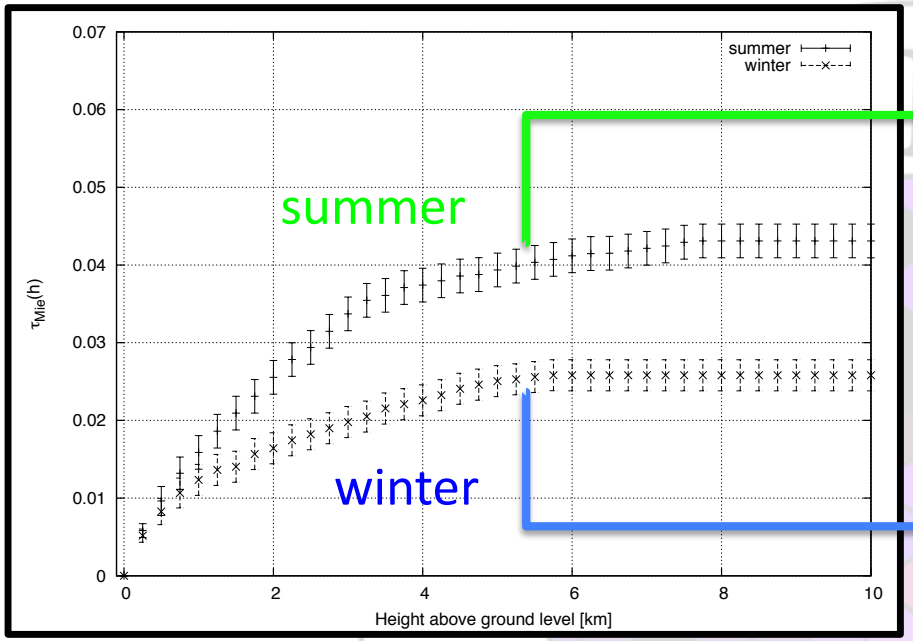


VAOD at each height

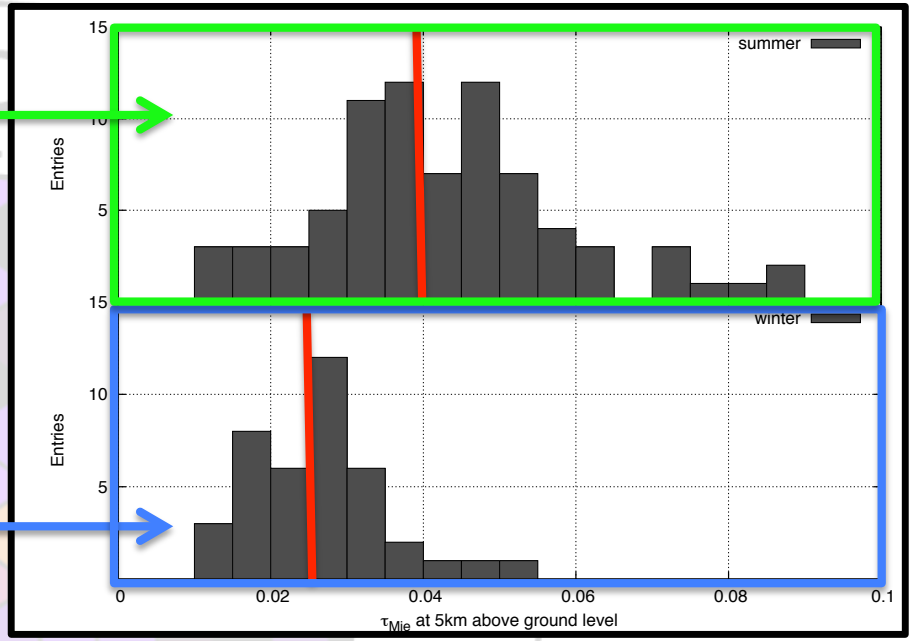
$$\alpha_{AS} = 0.0156 \times \exp(-h/0.12) + 0.0172 \times \exp(-h/2.12)$$

Aerosol scattering in different seasons

VAOD v.s. Height above ground



histogram of VAOD at 5km above ground



Median of VAOD for different seasons

Summer: **0.039** **+0.020 - 0.012**

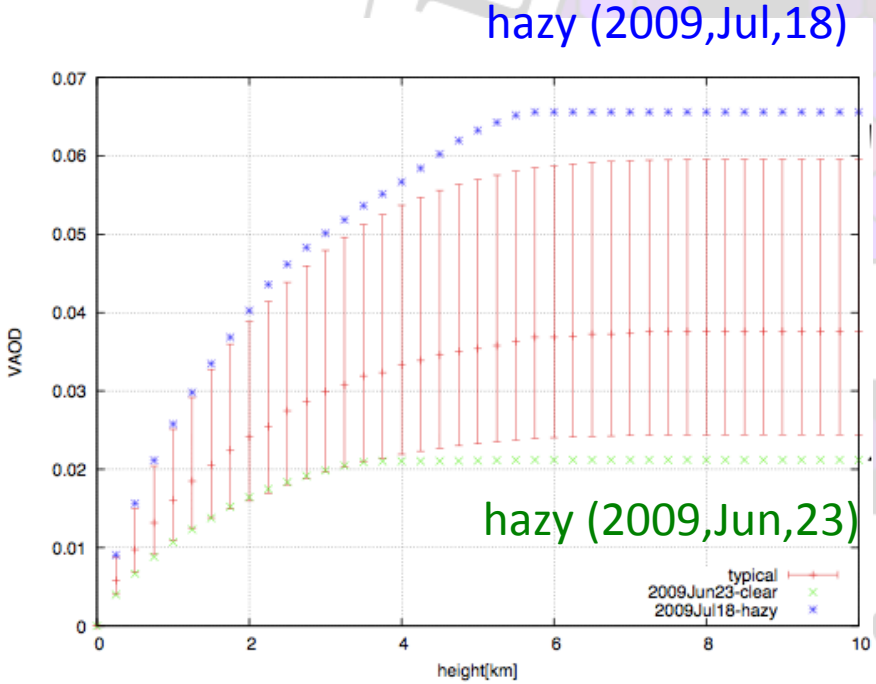
Winter : **0.025** **+0.010 - 0.007**

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

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

Typical v.s. Daily

- The air-shower is simulated by using the typical value for a transparency of the aerosol.
- The simulation value is reconstructed by using the observational data of the day when the atmosphere was hazy (or clear) for a transparency of the aerosol.



Condition of simulation

- Energy 10E19
- zenith = 0～60°
- azimuth = uniform
- core = 0～15km from TA center
- atmosphere : radiosonde

Typical v.s. Daily

Energy:

Typical: -4.12%

Hazy: 8.80% (+12.9%)

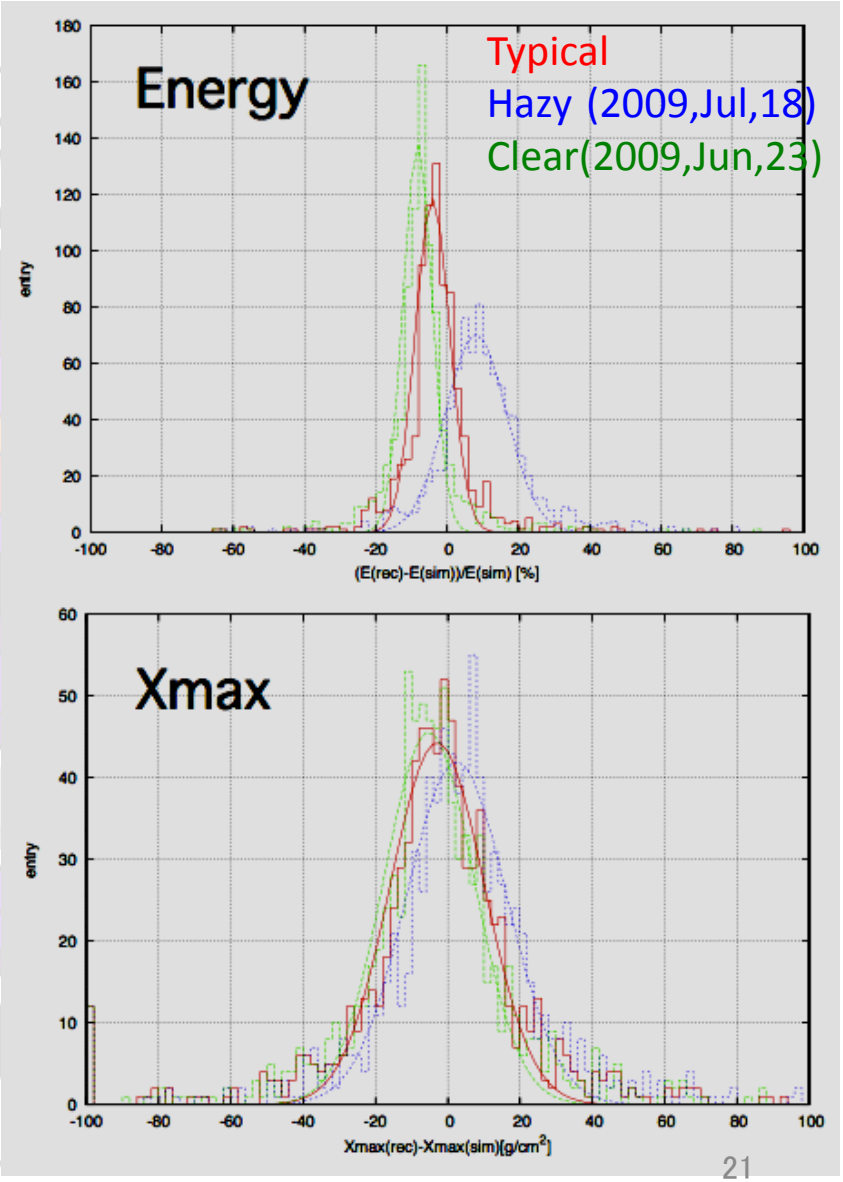
Clear: -8.27% (-4.15%)

Xmax:

Typical: -2.82g/cm^2

Hazy: 2.45g/cm^2 (+5.27g/cm^2)

Clear: -5.22g/cm^2 (-2.40g/cm^2)



Conclusions (transparency of aerosol)

- The typcal value used for the TA-FD analysis is determined.
- Extinction Coefficient at ground:$0.034 \pm {}^{0.015}_{0.013}$ km^{-1}
- Attenuation Length at ground :$29.4 \pm {}^{16}_{10}$ km
- Scale Height :1km

- However, the typical value in which details are shown is indicated by

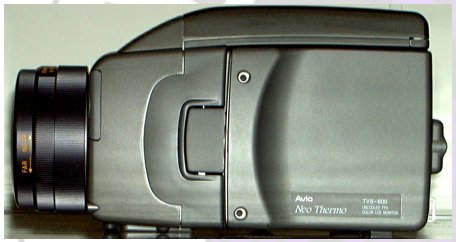
$$\alpha_{AS} = 0.0156 \times \exp(-h/0.12) + 0.0172 \times \exp(-h/2.12)$$

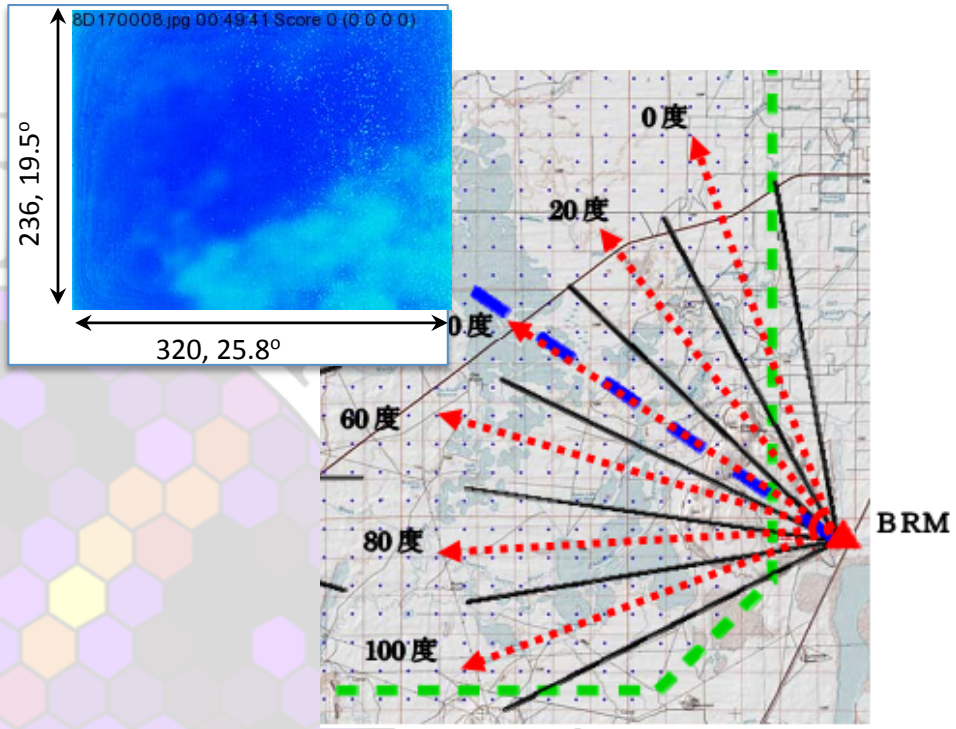
- The effect of the aerosol component in summer is 1.5 times greater than that in winter.
- When the typical value is used, the upper of error of reconstruction energy is 12.9% or less in 10^{19}.

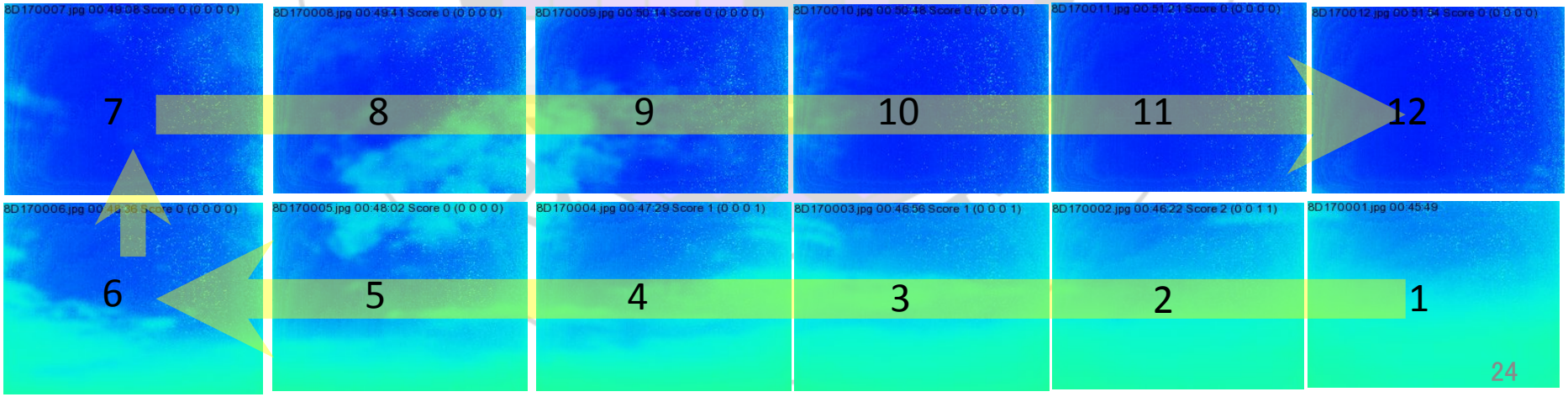
Cloud monitor with IR camera

TA IR camera

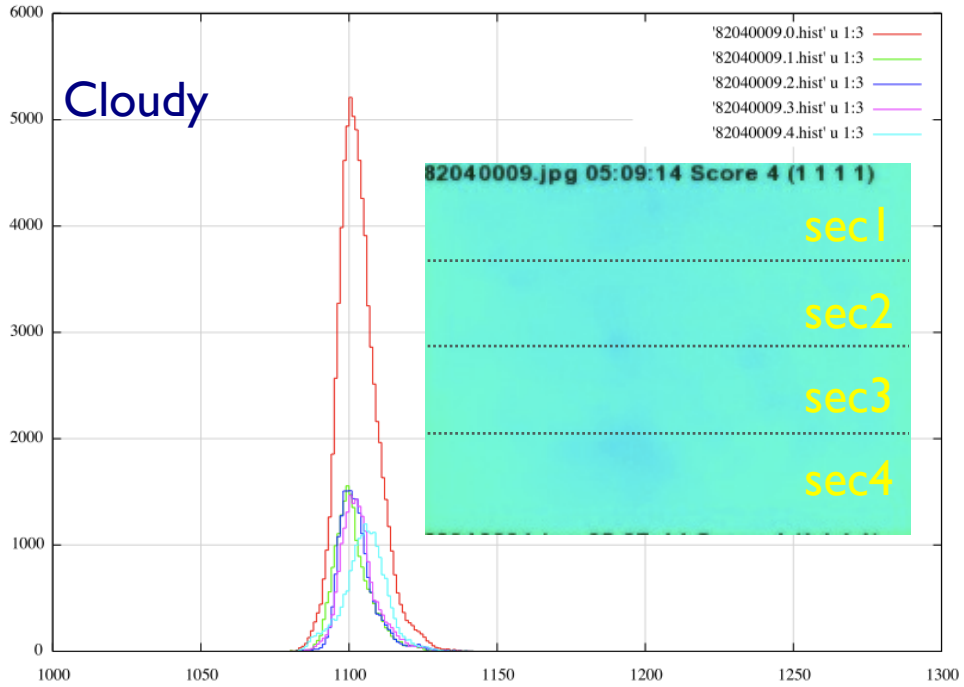
- Sensitive 8 ~ 14 us
- 320 x 236 pixels
- 25.8° x 19.5°
- Near the LIDAR dome
- Once per 50 min (~2009Jul) or per 30min (2009Jul~)



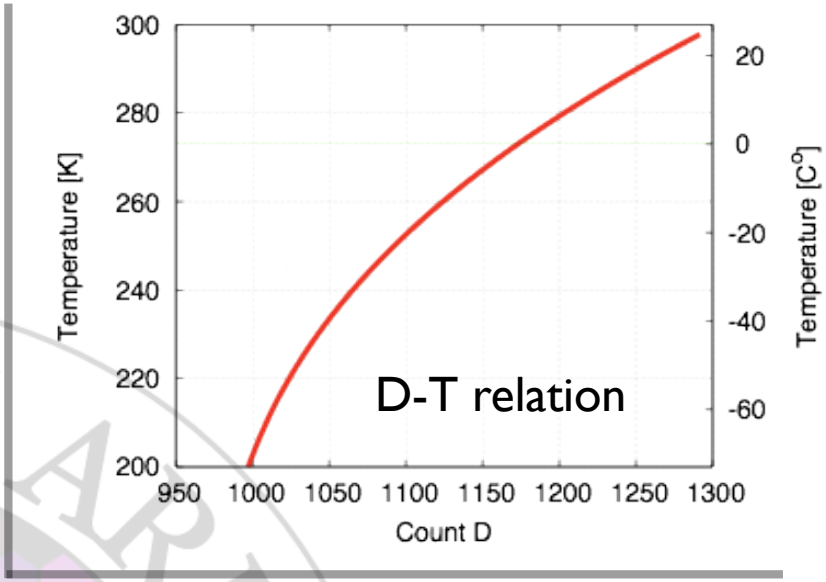


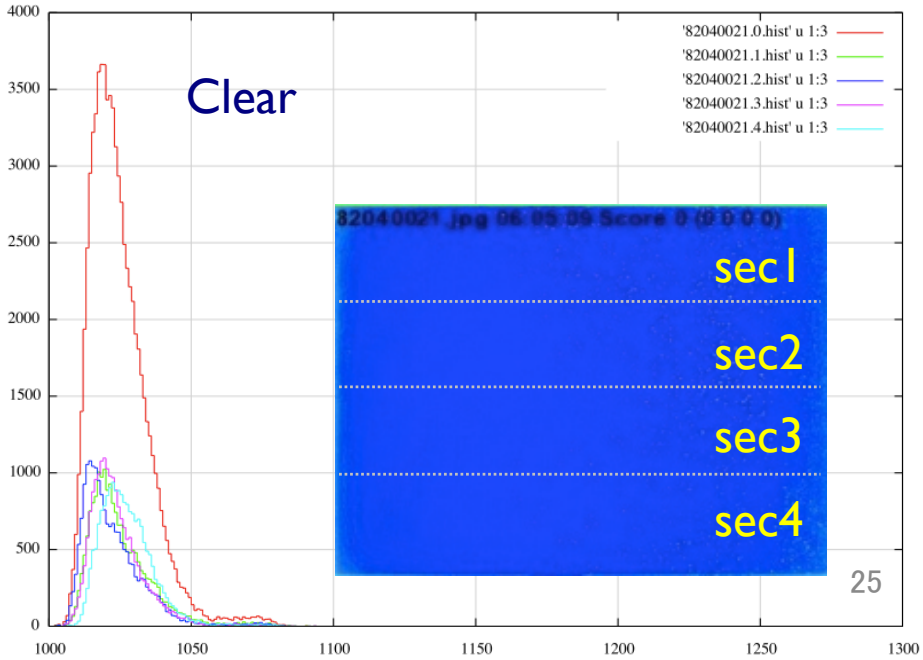


IR Sky Images



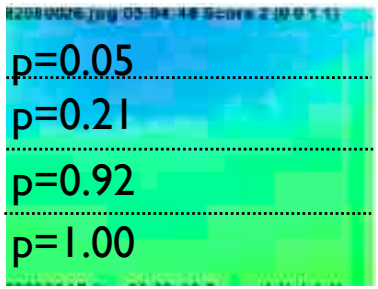
D: Pixel Data





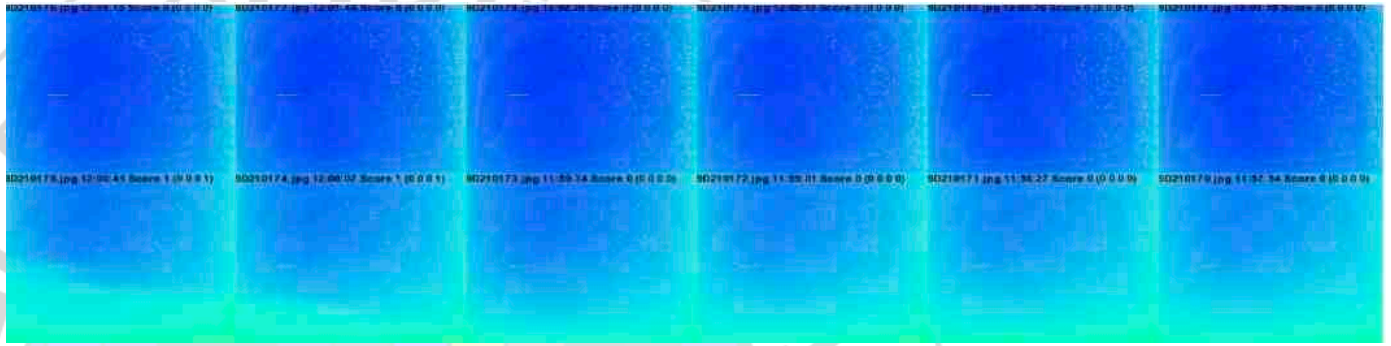
- An IR image are split into 4 "sections" horizontally in data analysis, because lower elevation region look warmer.

Examples



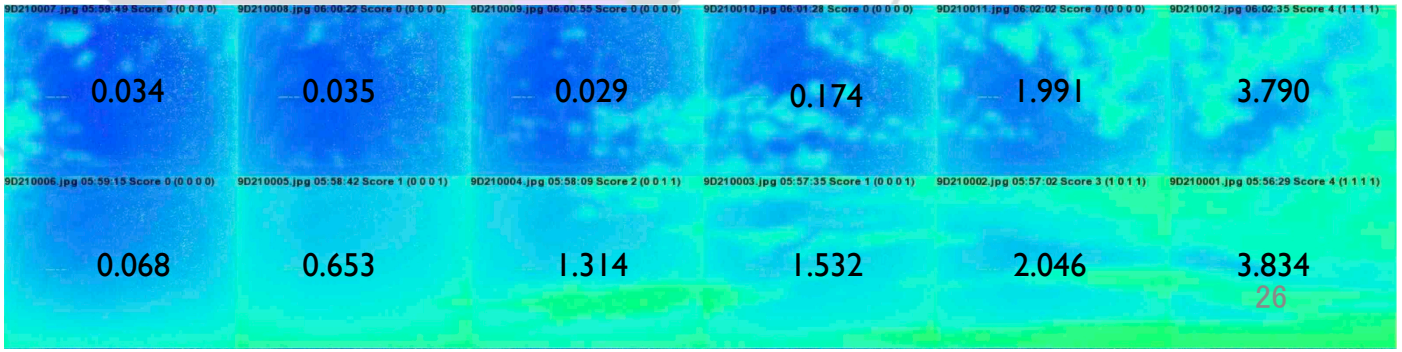
Score = 2.18/4.00

Total: 1.05/48.0

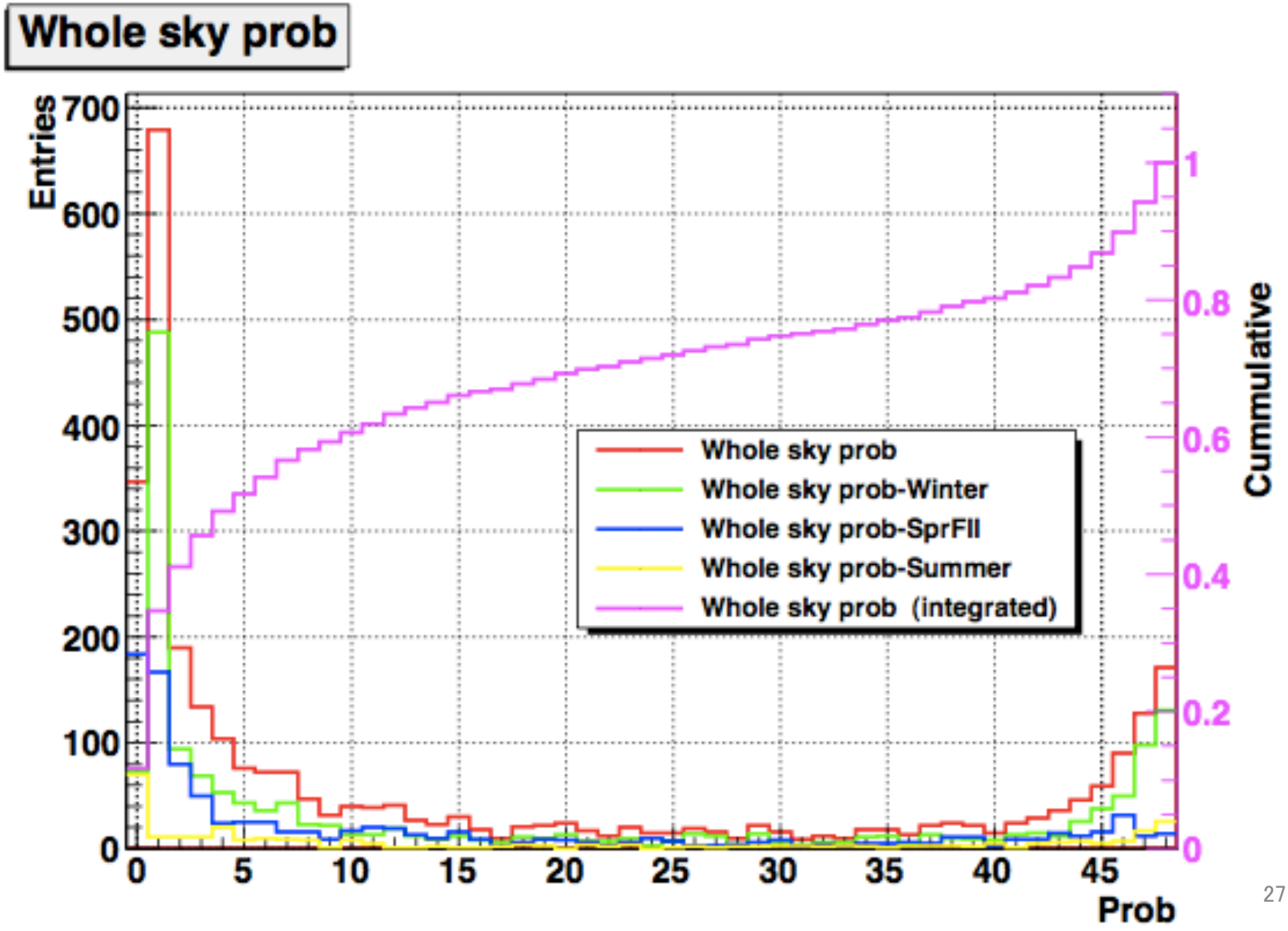


Total: 47.0/48.0

Total: 13.0/48.0



Sum of Scores of All the Directions (0 ~ 48)



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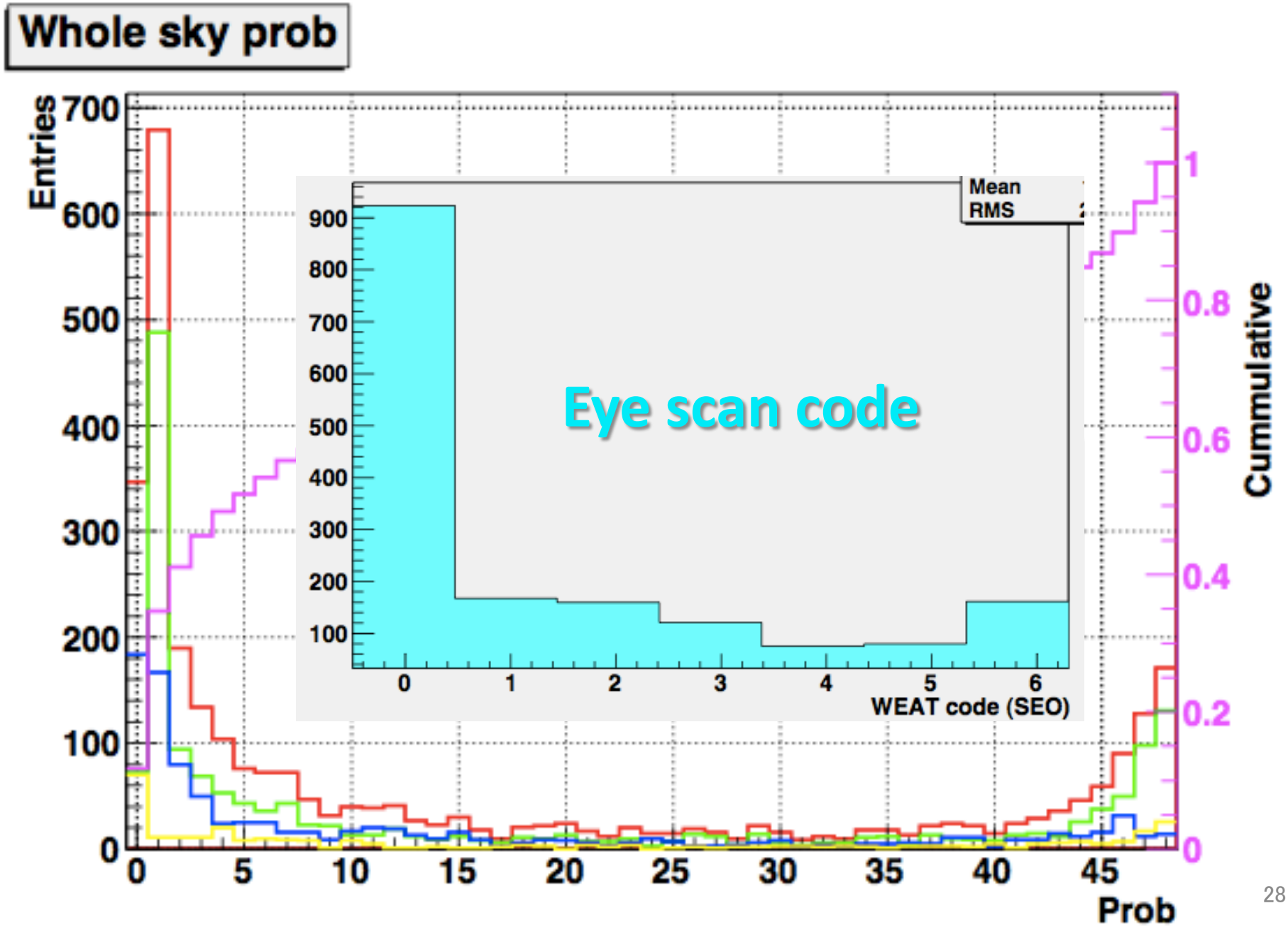


Conclusions (Cloud monitor)

- Cloud existence is determined each "*section*"
- IR score and Eye-scan code is consistent.

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)

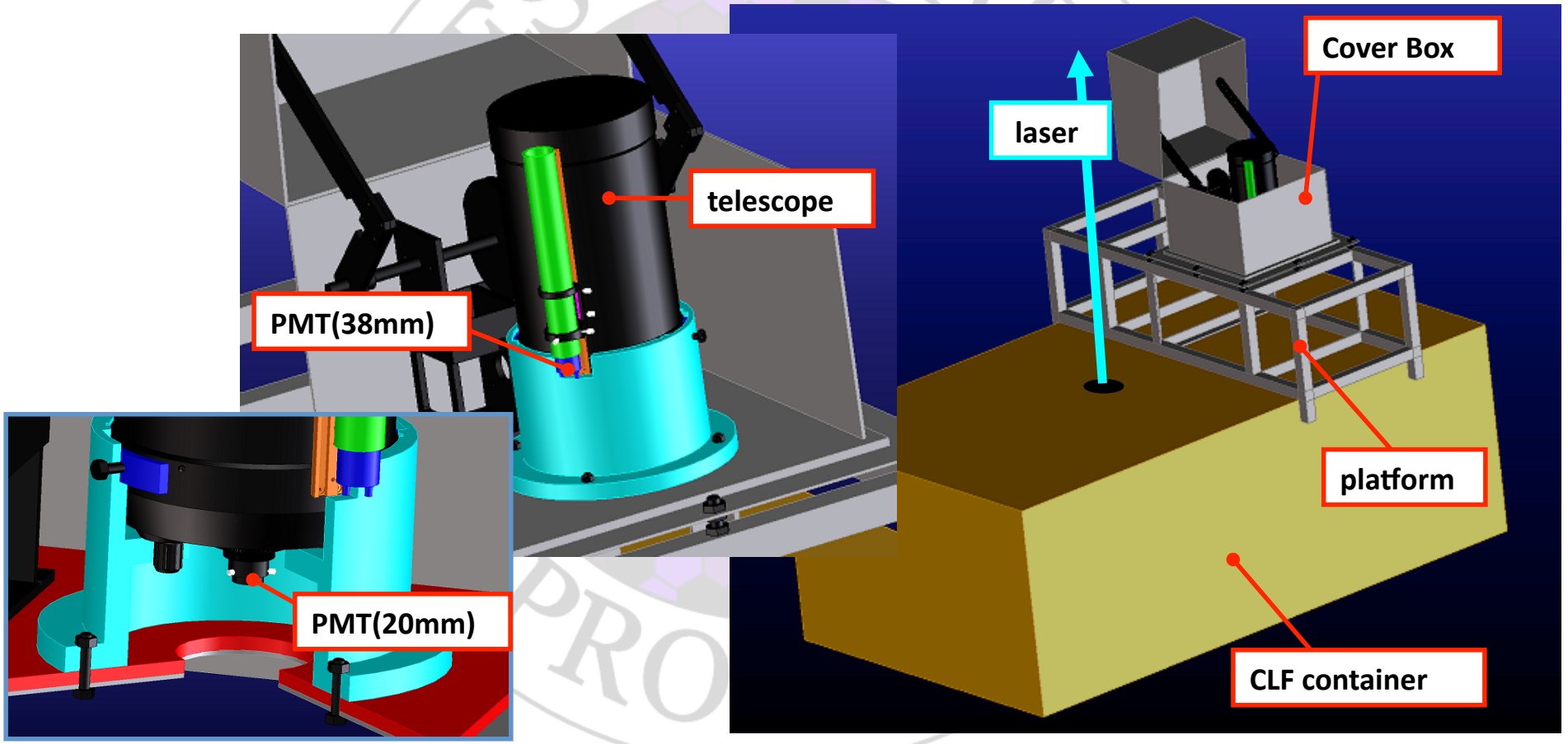
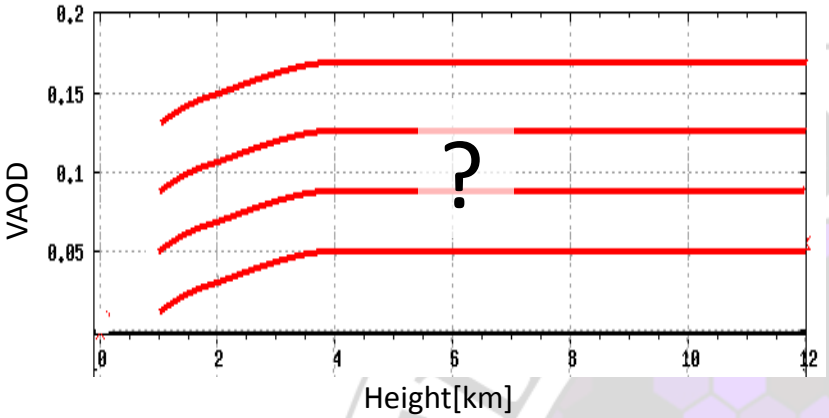


Fig. general drawing of LIDAR@CLF

Analysis policy of LIDAR@CLF

Analytical result only of LIDAR@CLF



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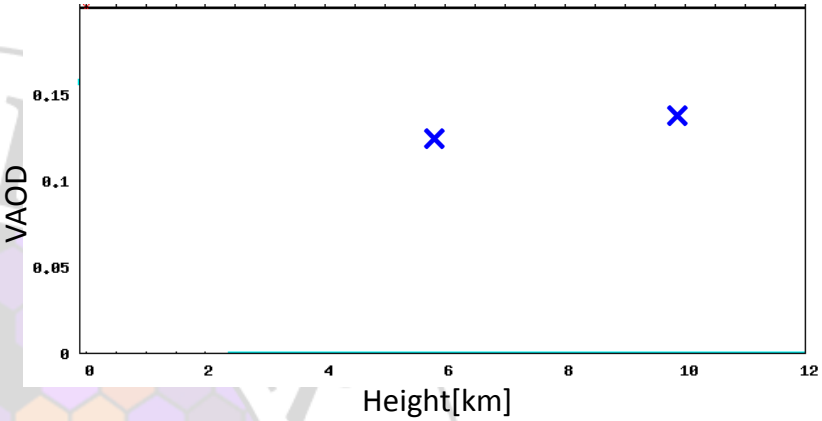
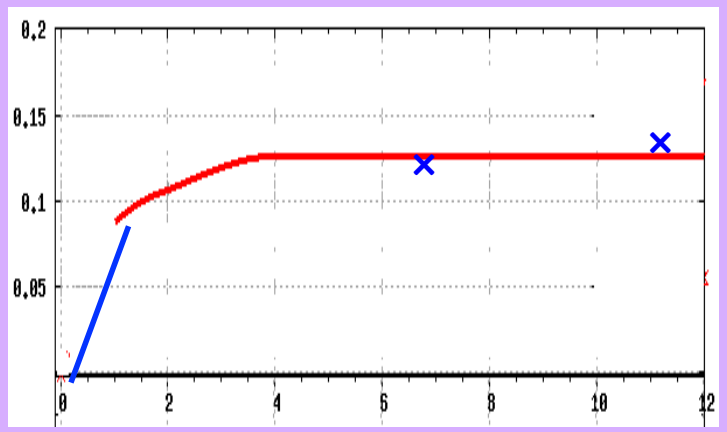
Analytical result only of CLF



Normalized by VAOD of CLF.

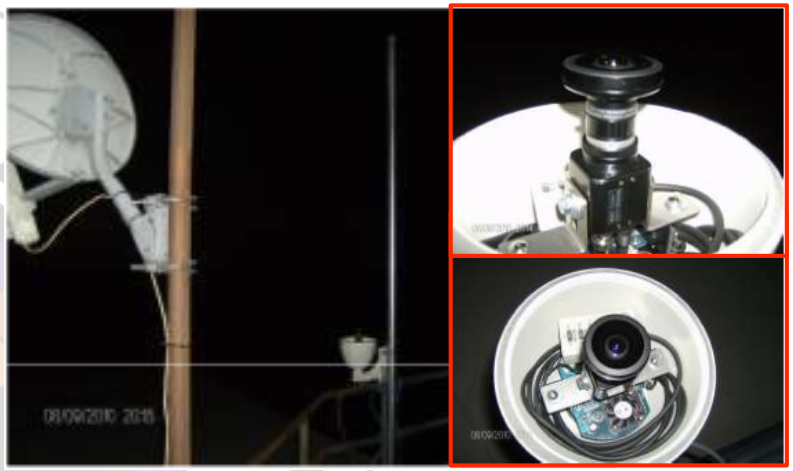


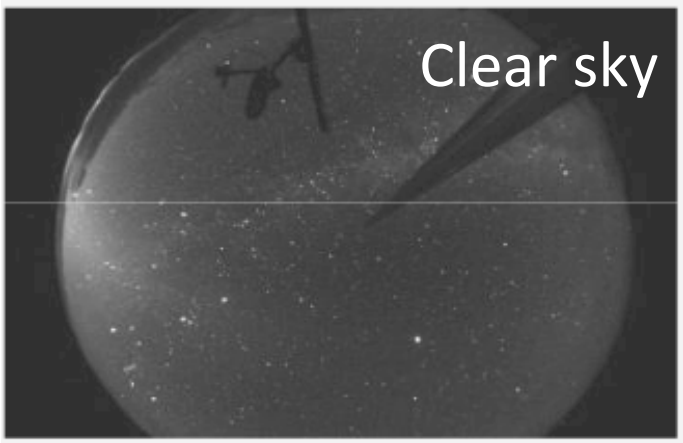
Analytical result of LIDAR@CLF and CLF

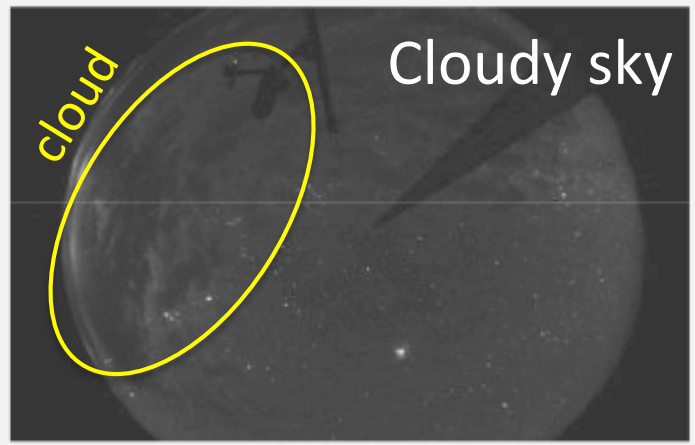
- Shape of VAOD according to height is determined from LIDAR@CLF.
- VAOD at high altitude is determined from the analysis of CLF.

CCD camera for cloud monitor

- CCD camera of the fish-eye lens is set up in the FD station (BR & LR) rooftop.
- The picture is taken in every 15 second, and the integration value of the data of 1 minute is recorded.







END