China-Japan Collaborative Site Testing in West China
- A report by Japanese group -

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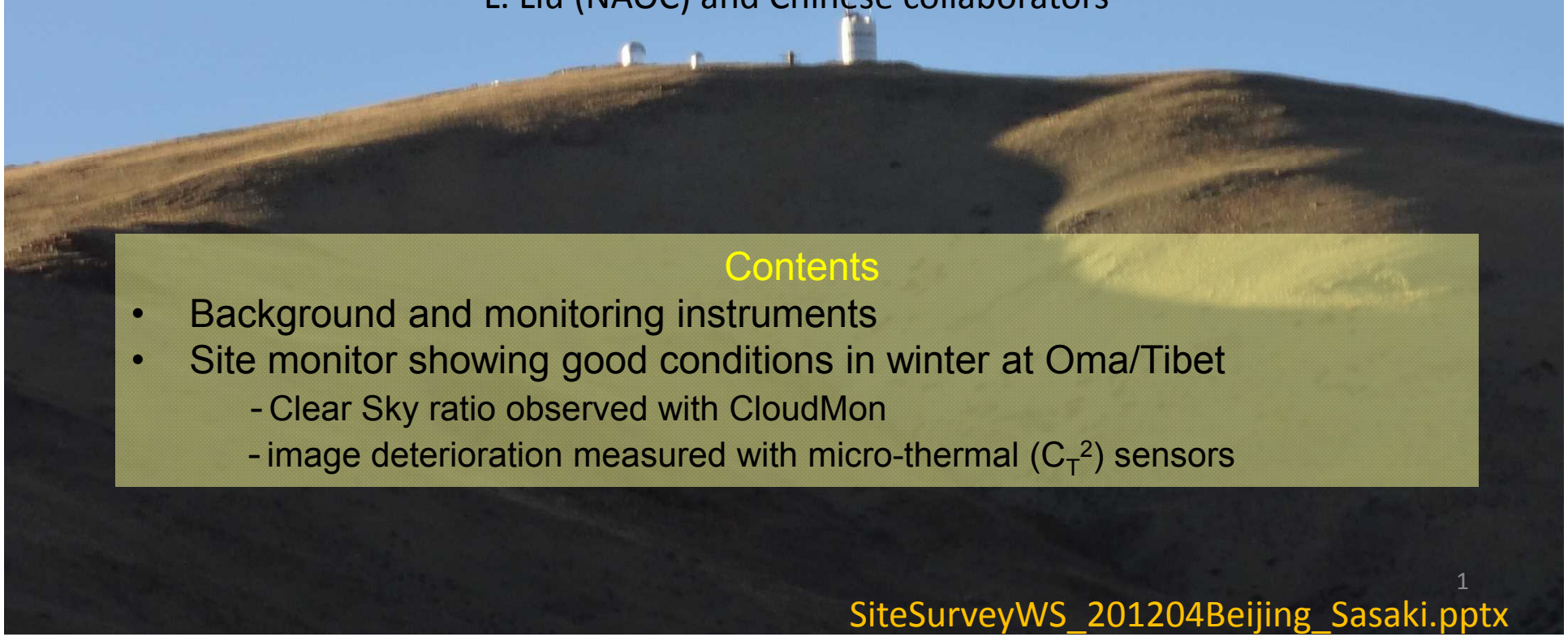
L. Liu (NAOC) and Chinese collaborators



Contents

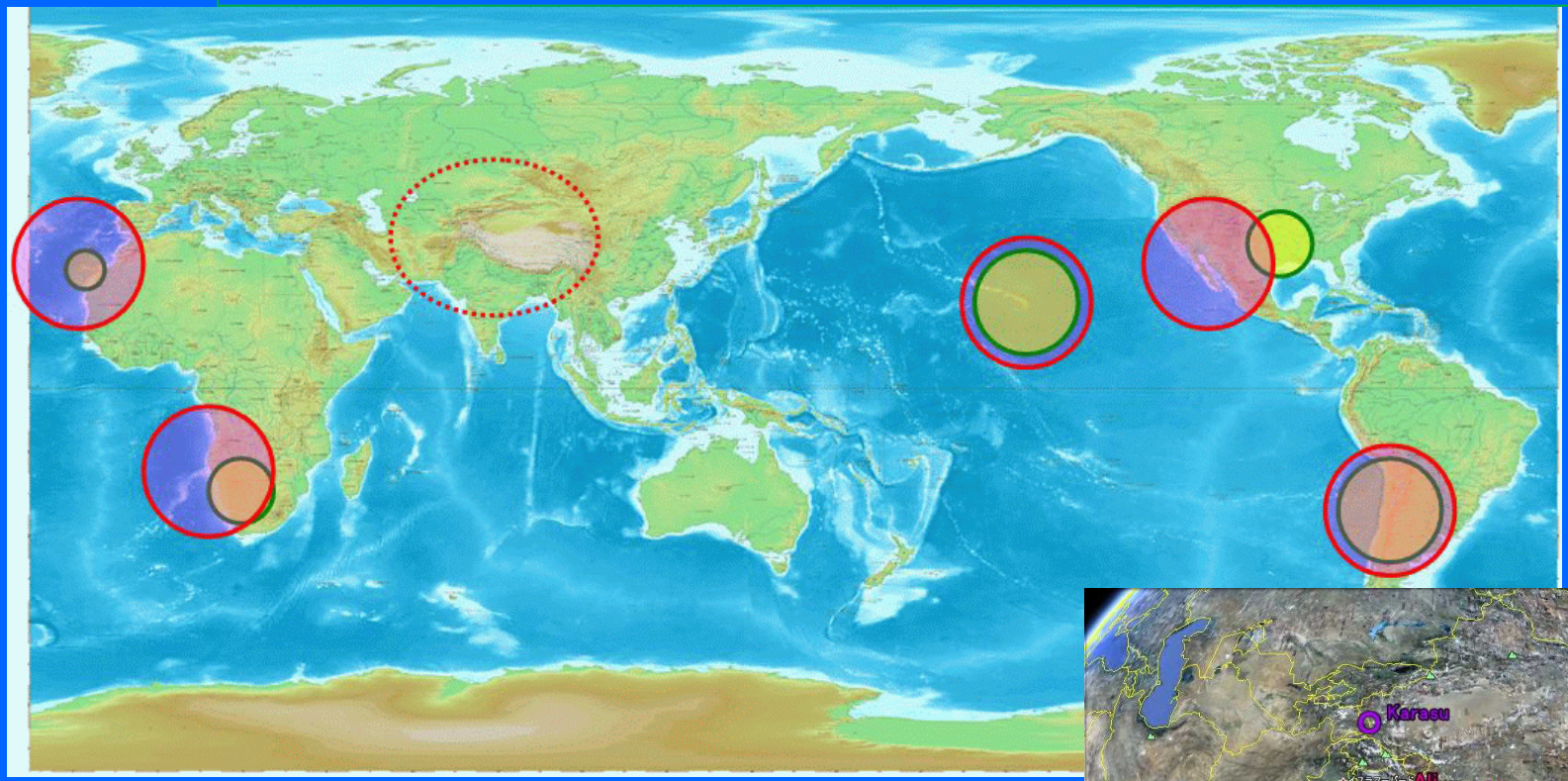
- Background and monitoring instruments
- Site monitor showing good conditions in winter at Oma/Tibet
  - Clear Sky ratio observed with CloudMon
  - image deterioration measured with micro-thermal (C_T^2) sensors

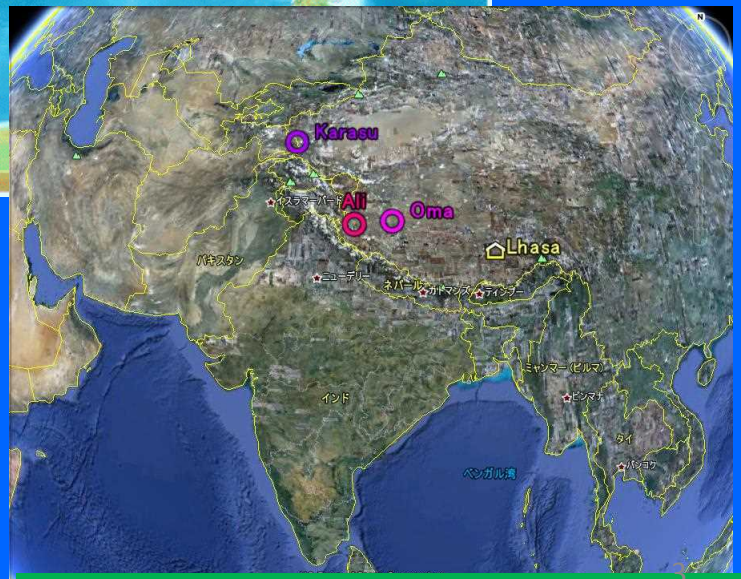
Collaborative Site Testing in West China

Summary

1) **Site Survey and testing** has been conducted since 2003, led by Prof. Y. Yao, and two weather-monitoring stations have been settled at **Karasu** (Xinjiang) and **Oma** (Tibet).
2) Japanese team has joined the site survey project after the workshop at Lhasa, 2004. We introduced **MIR cloud monitor** cameras , atmospheric micro-turbulent $\mathbf{C_T^2}$ sensors, and weather stations at both sites.
3) At **Oma** site, **cloud monitor camera** revealed excellent sky conditions in winter, but not good in summer.
4) Nominal seeing measured with C_T^2 was less than 0.1 arcsec up to 36m height in Nov. 2008. We must conduct seeing measurement through whole atmosphere w/ DIMM/MASS/(SNODAR) to evaluate seeing condition at the site soon.
5) Strong winds have been observed at **Oma** in winter season, which may affects seeing seriously.
6) We are settling site survey instruments at possibly best site near **Ali** in west Tibet.

A site in west Tibet is in an important location for global astronomical observation network





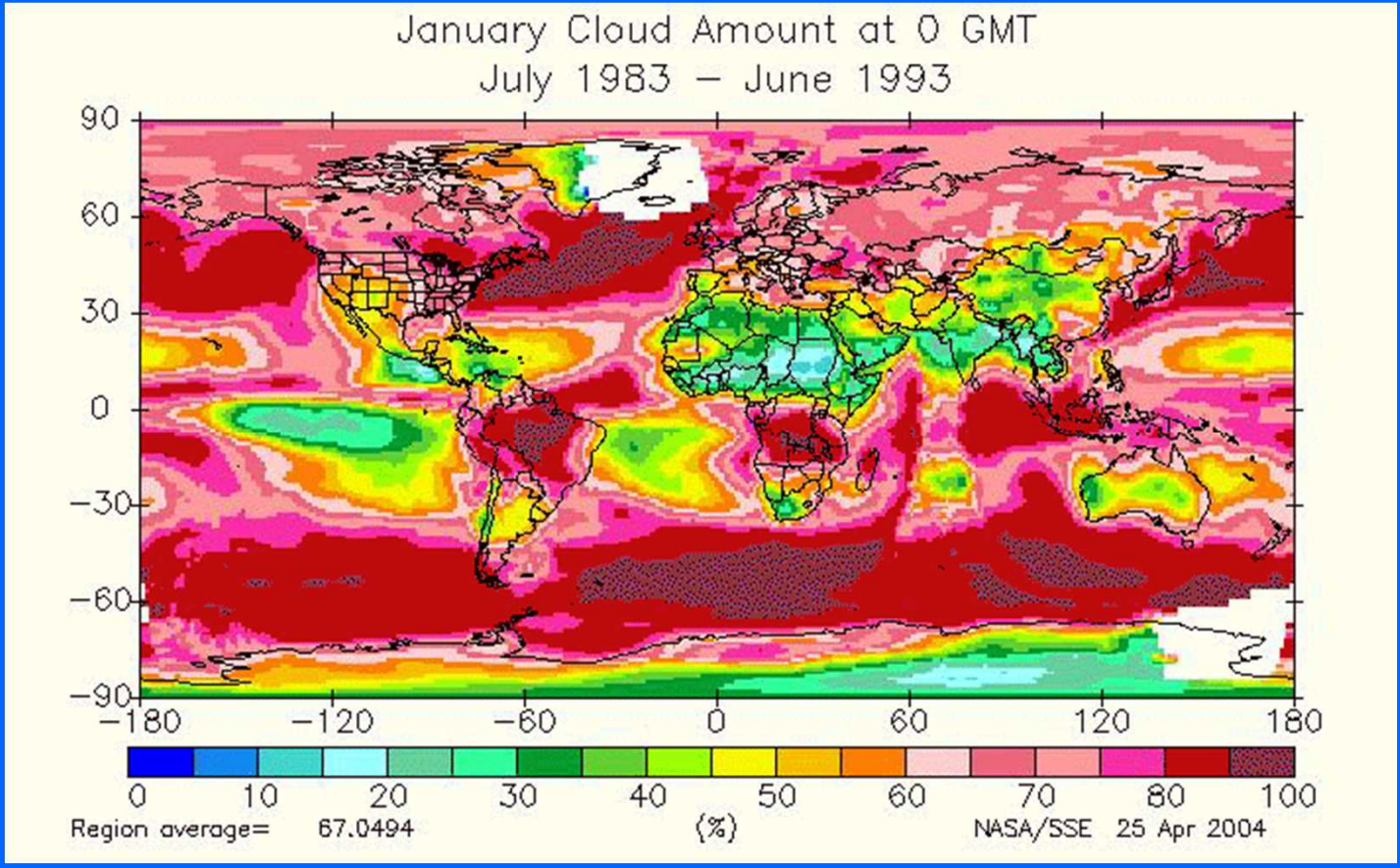
sites in west China; Karasu, Oma, and Ali

In Planning phase of ELT, west China is one of candidate sites

Dr. Sarazin (ESO) showed a global weather map at SPIE at Kona, 2002 .

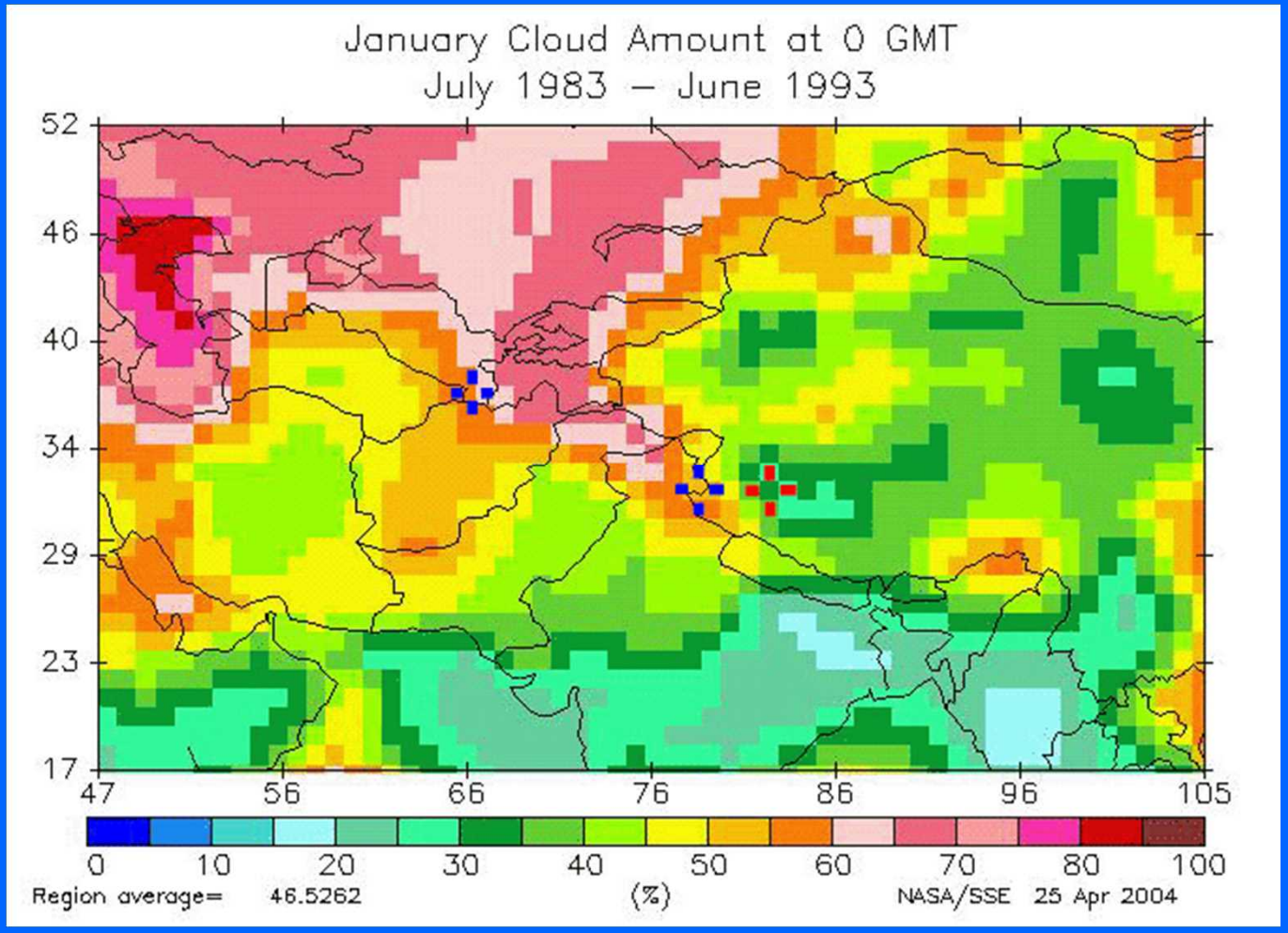
Global Cloud Distribution

Refer to **http://eosweb.larc.nasa.gov/sse/**
Meteorology and Solar Energy
Global/Regional Plots



Cloud map around west China

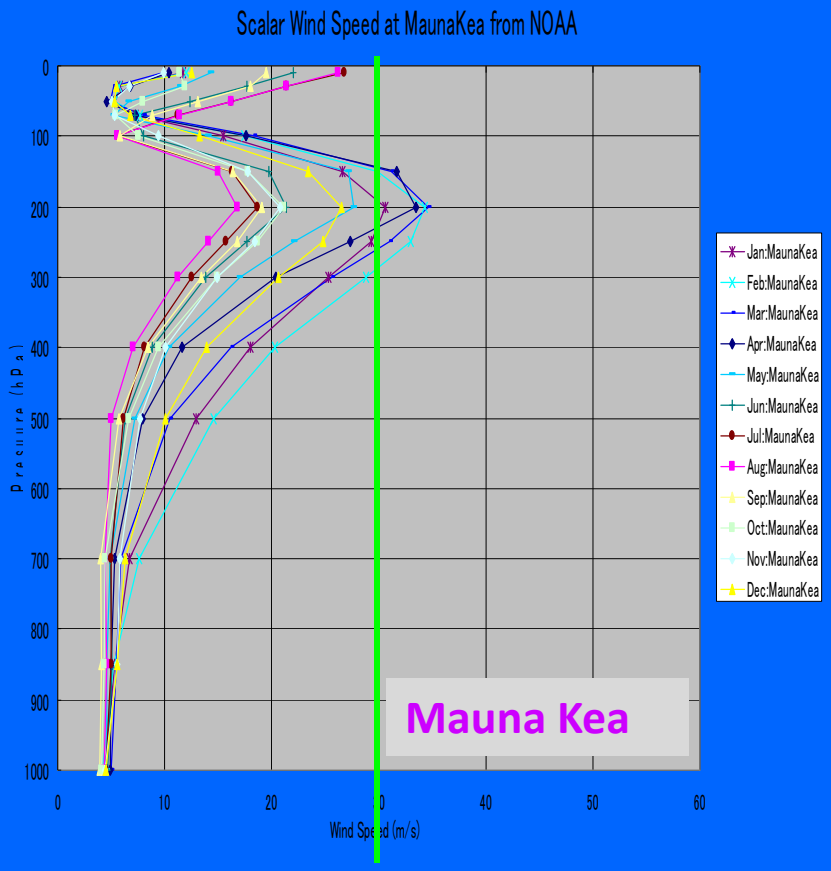
Arranged only for night data.
Two blue crosses show ***Hanle*** (India) and ***Maidanak*** (Uzbekistan). Red cross shows candidate site in **Tibet**.



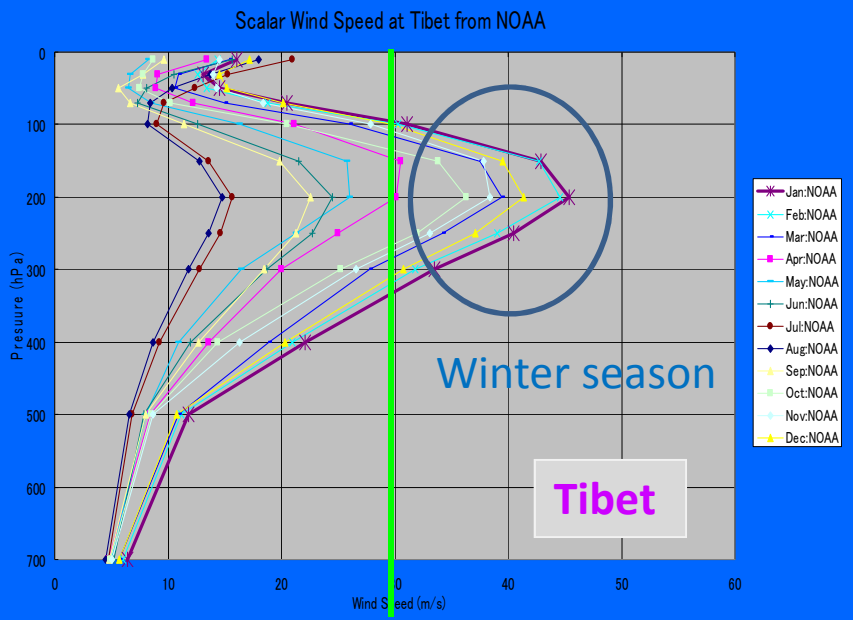
Wind Speed at Tibet and Mauna Kea at 200mb

Wind speed at 200mb (altitude～12000m) shows correlation with seeing size

Does it mean bad seeing during winter at Tibet? (Vernin 1986 SPIE 628,142)

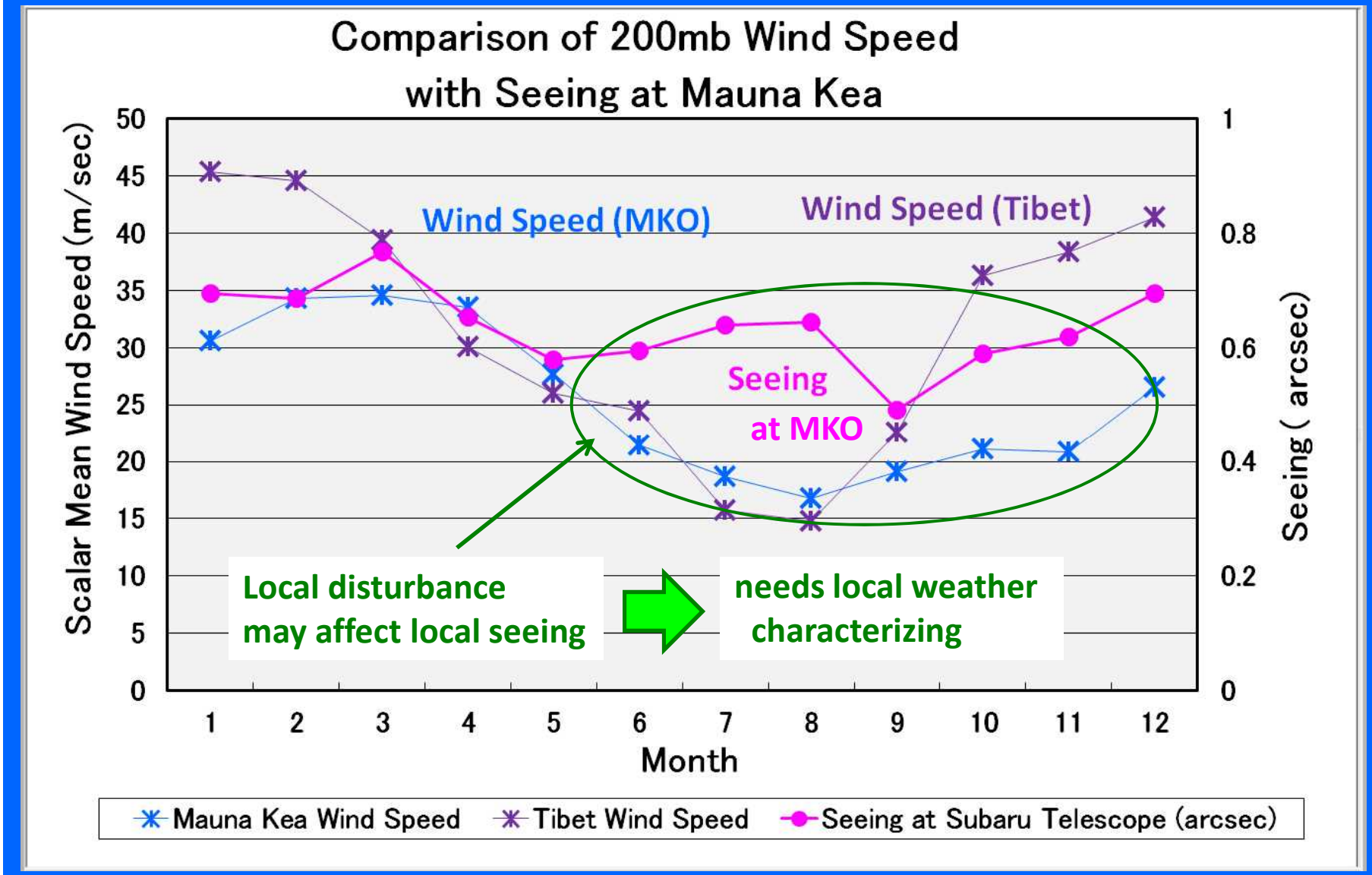


30m/s



30m/s

From ¥01SatelliteData¥NOAAData¥AstronomicalSites¥AllSites200mb.xls



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Site monitoring instruments available and/or planned

Instrument	Method	Measured value	Height range
Weather Station*$	Temperature, Humidity, Wind, Pressure Rain, (Sunshine, IR radiation)	Meteorological data	at several m
Dust counter*	Particle counter	Dust particle	at several m
Visible whole-sky camera$	visible CCD camera	Night sky	through atmosphere
IR Cloud monitor*	10μm-band MIR camera	Cloudiness	through atmosphere
DIMM$	Differential Image Motion Monitor	Seeing	through atmosphere
MASS$	Multi-Aperture Scintillation Sensor	Scintillation	1km to several 10km
SCIDAR$	Scintillation Detection and Ranging	Scintillation	1km to several 10km
CT2 sensor*	Micro-thermal Turbulence in Surface Layer	Turbulence	0 m to several 10 m
SNODAR (planned)	Surface layer Non-Doppler Acoustic Radar	Scintillation	8m～200m
SODAR (NOT exists)	Sound detection and ranging	Scintillation	15m～1-2km

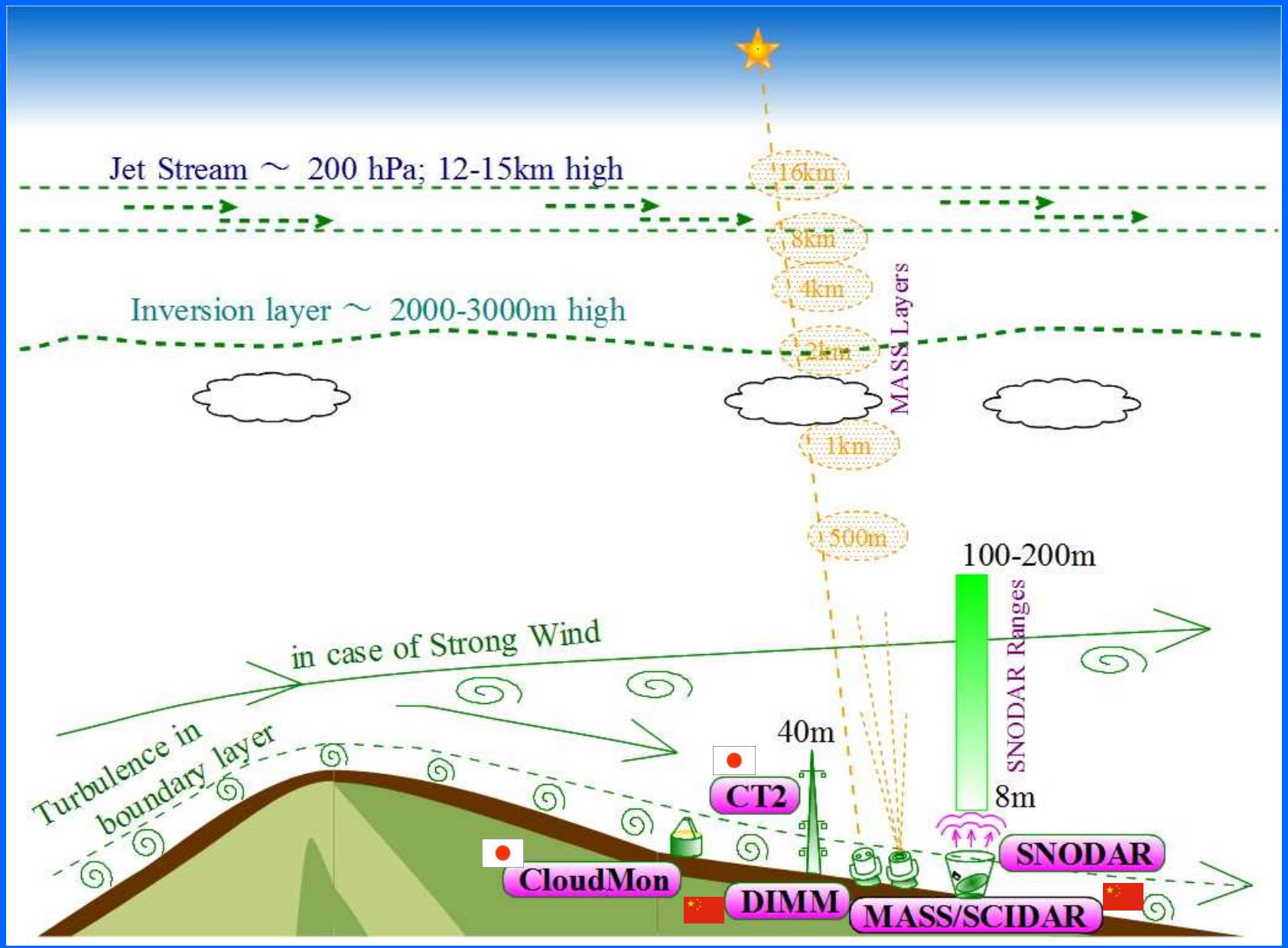
$ * Currently available instruments ($China , *Japan)

(at Ali)

Cloud Monitor Weather Station

CT2 sensors on 40m tower

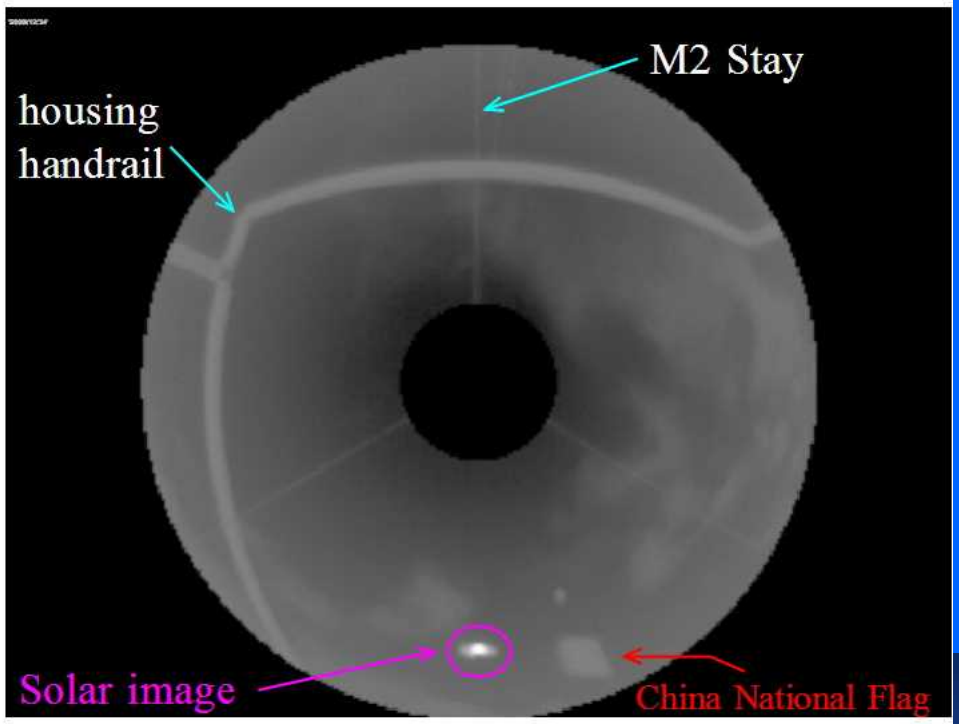
(at Karasu)

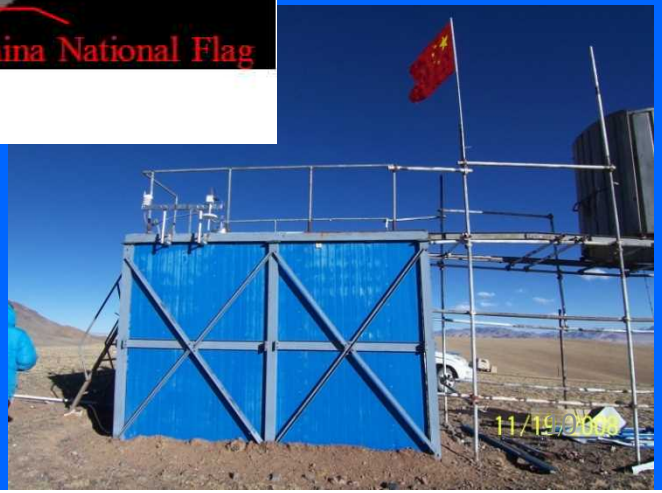

Jet Stream ~ 200 hPa; 12-15km high
Inversion layer ~ 2000-3000m high
16km
8km
4km
2km
1km
500m
MASS Layers
100-200m
SNODAR Ranges
in case of Strong Wind
Turbulence in boundary layer
40m
8m
CT2
CloudMon
DIMM
SNODAR
MASS/SCIDAR

Cloudiness observed w/ CloudMon at Oma in 2008 and 2009

A Cloud Monitor
on housing roof
at Oma, Tibet

FOV of Cloud Monitor

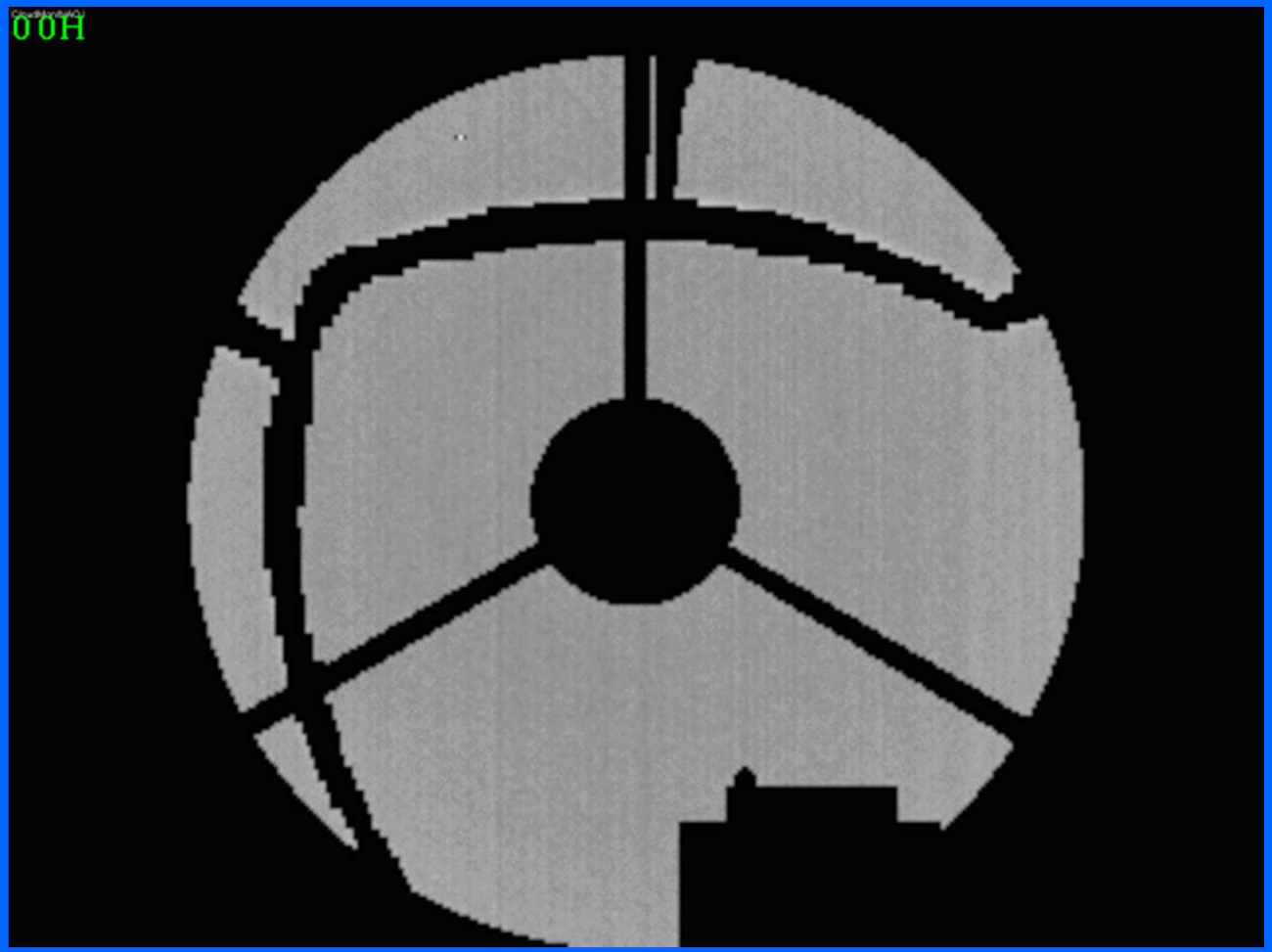




Sample Images of CloudMon at Oma on 2008/12/24

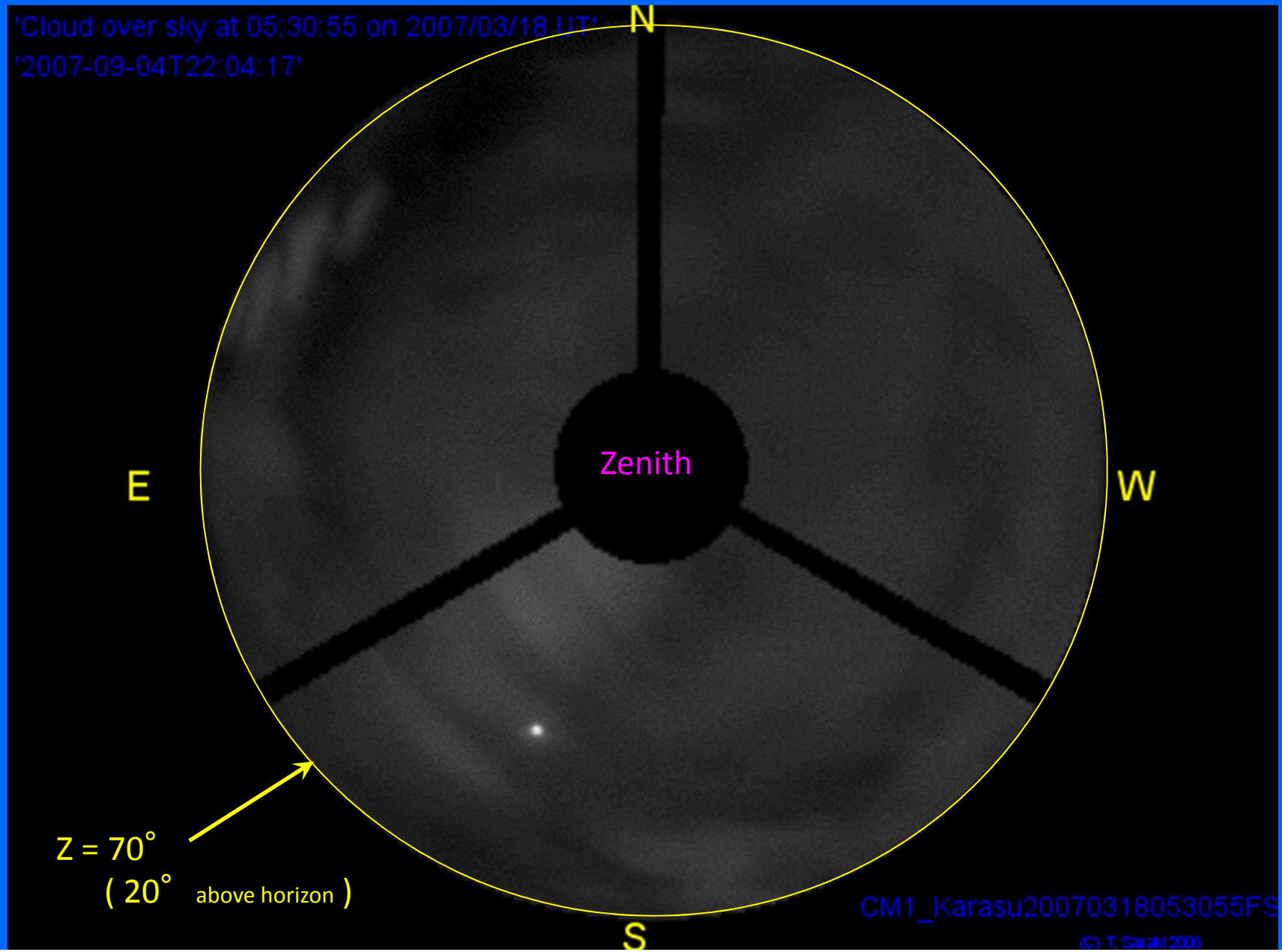
All-sky images, every 1 hous, taken w/Cloud Monitor at Oma on 2008-12-24

Ground-based MIR images (Thermal-Eye 2000B Camera, 7-14 μm (320x240 pixel array), 1 frame/ 1 min)



CloudMonitor Image

2007 March 18 at Karasu



Error estimate of cloudiness with Cloud Monitor

Data Analysis

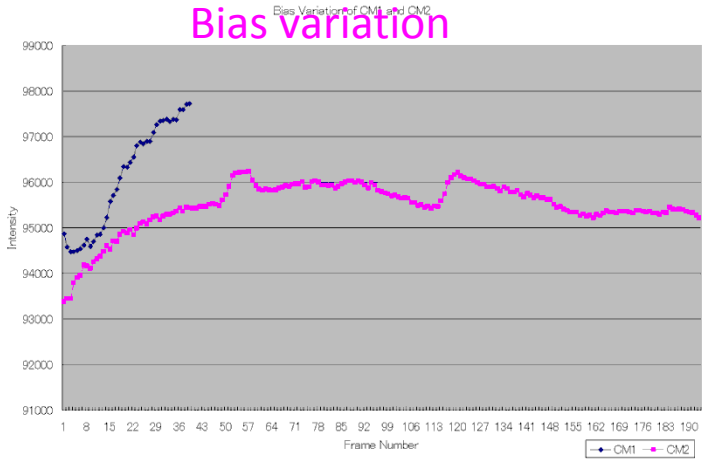
1) Flat-Fielding, 2) sky subtraction, and 3) masking

Estimated Errors

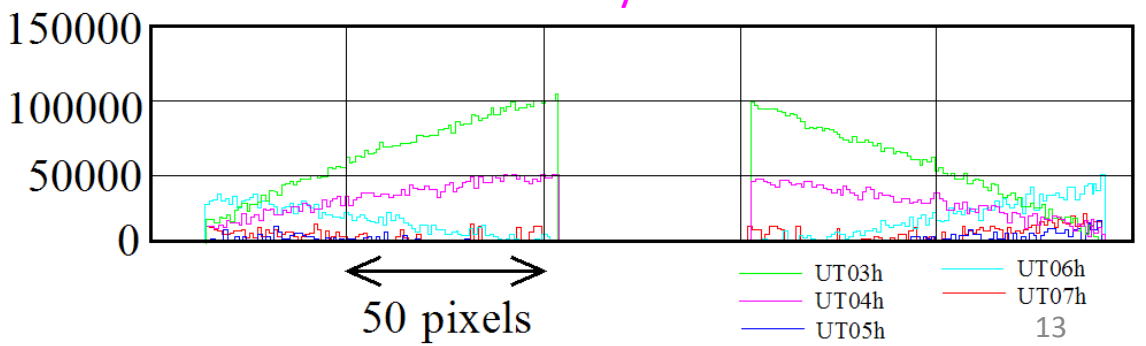
1) Flat-Fielding image with covered-wth-cap camera with variation of 3.4%.
2) Background intensity variation of 7.7% of flat-fielded images;
   a part of variation are due to solar radiation,
   but other might be sensitivity variation of the MIR camera.
3) time-dependent variation of sensitivity across the image of 10 - 12%

In total, intensity error might be of 14%.
Due to this large error, we use CloudMonitor images
only for qualitative evaluation of cloudiness so far.

Bias variation



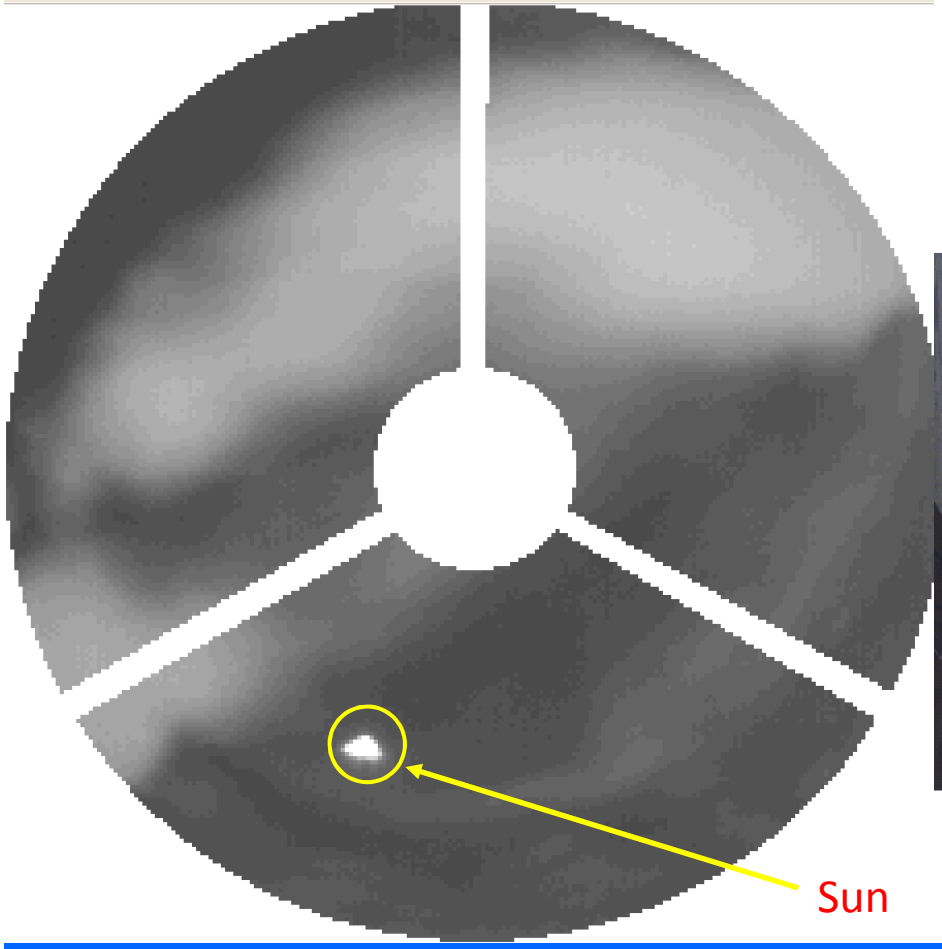
Sensitivity variation



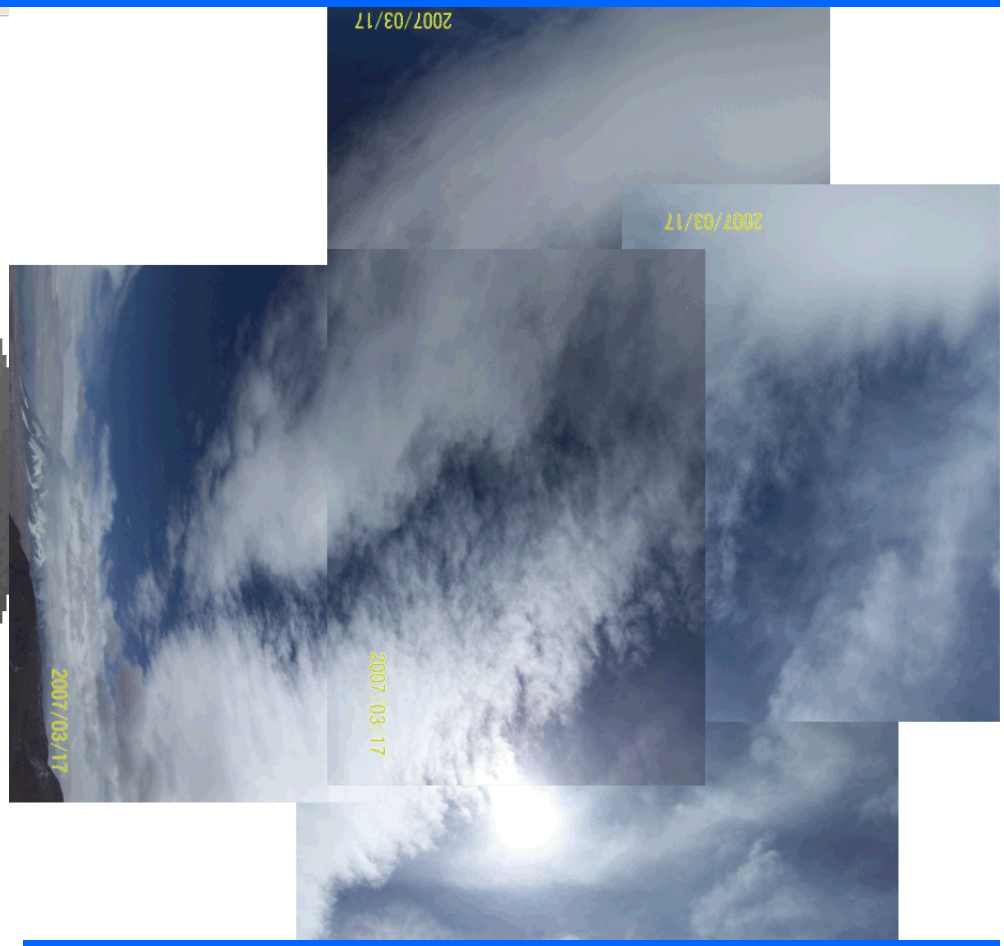
Comparison between CloudMon (MIR) image and Visible image

on 2007 March 17 05:35:55UT

Using intensity of solar image → CloudMon detection limit of Cloud w/ 5 % extinction



CloudMonitor image
(MIR)

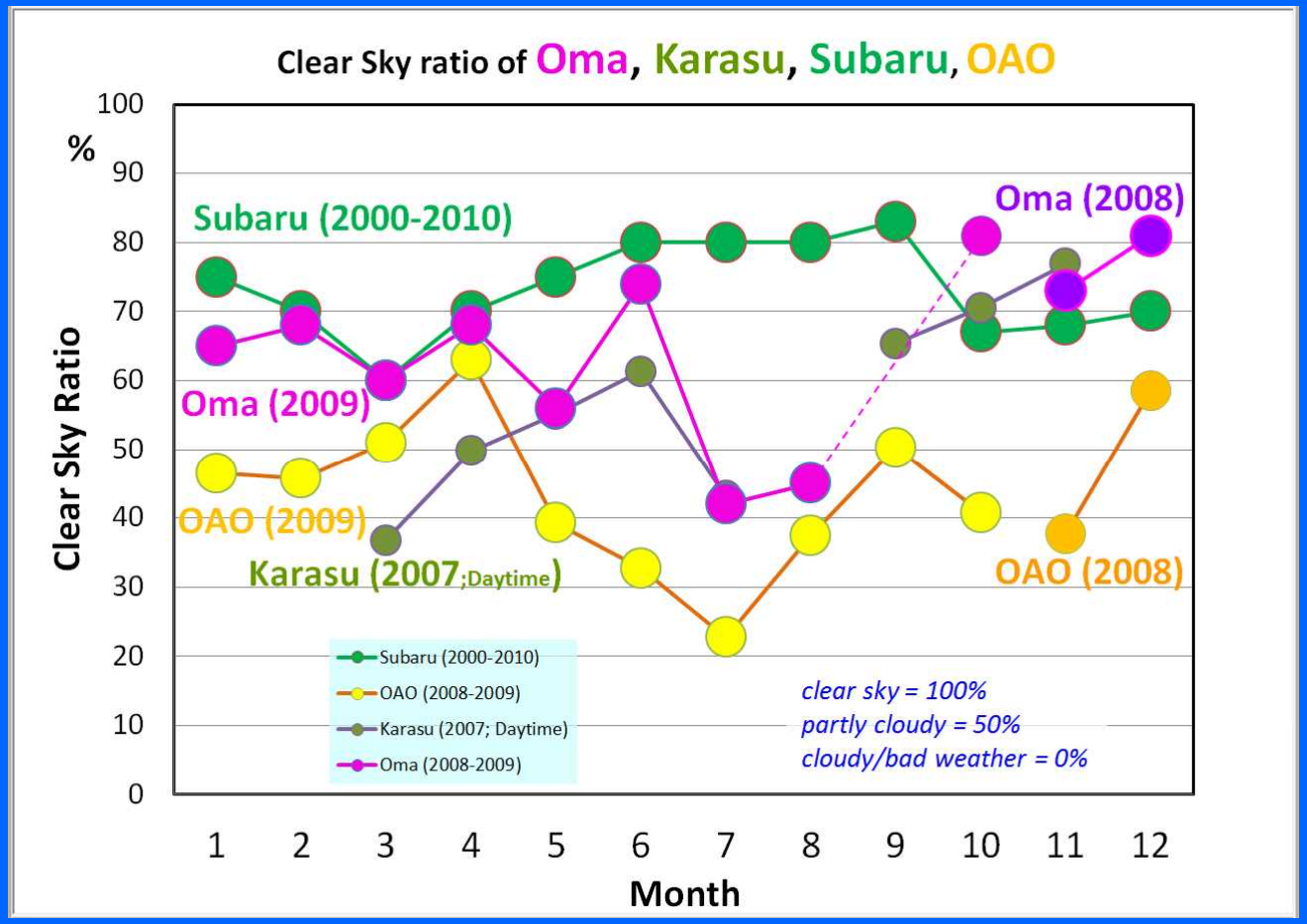


Digital camera
(Visible)

Cloudiness judged w/ CloudMon Images at Oma in 2008 Dec.

Oma	天候概況判断	○	快晴	Clear
		△	雲あり	Fine/fair/partly cloudy
		×	降雨	Cloudy/rainy

		昼間	夜間																				
UT	0h	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	12h	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h
2008/12/1	△	△	△	△	△	△	△	△	△	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
2008/12/2	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
2008/12/3	○	○	△	△	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
2008/12/4	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
2008/12/5	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
2008/12/6	○	○	○	○	○	○	○	○	○	△	△	△	△	△	△	○	○	○	○	○	○	○	○	○
2008/12/7	○	○	○	△	○	○	○	○	○	△	△	△	○	○	○	○	○	○	○	○	△	△	△	△
2008/12/8	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	○	○
2008/12/9	○	○	○	○	○	△	△	△	△	△	△	△	△	△	○	○	○	○	○	○	○	○	○	△
2008/12/10	○	○	○	○	○	○	○	△	△	△	△	△	○	○	○	○	○	○	○	○	○	○	○	○
2008/12/11	○	○	○	○	○	○	○	○	△	○	△	○	○	○	○	○	○	○	○	○	○	○	○	○
2008/12/12	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
2008/12/13	○	○	△	○	○	○	○	○	○	○	○	○	△	△	△	○	○	○	○	○	△	○	○	○
2008/12/14	△	○	△	○	○	○	○	○	○	○	○	○	○	○	△	○	○	○	○	○	○	○	○	○
2008/12/15	○	○	△	○	○	○	△	△	△	△	△	△	△	○	○	○	○	○	○	○	○	○	○	○
2008/12/16	○	○	○	○	○	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△
2008/12/17	△	△	△	△	△	△	△	△	△	△	△	△	○	○	○	○	○	△	○	○	○	○	○	○
2008/12/18	○	○	○	○	○	○	○	○	○	○	○	△	△	△	△	△	△	△	△	△	○	○	○	○
2008/12/19	△	○	○	○	○	○	△	△	△	△	△	△	△	△	△	△	△	△	○	△	△	△	△	△
2008/12/20	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	○	○	○	△	△	○
2008/12/21	○	○	○	○	○	△	△	△	△	△	△	△	△	○	○	○	○	○	○	○	○	○	○	○
2008/12/22	△	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	△
2008/12/23	△	△	△	○	△	△	△	△	△	△	△	△	△	△	△	△	△	○	○	○	○	○	○	○
2008/12/24	○	○	○	○	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	○	○	○	○	○
2008/12/25	○	○	○	○	○	△	○	△	○	○	○	○	○	○	○	○	○	○	△	△	△	△	○	○
2008/12/26	○	○	○	○	○	△	△	△	○	△	△	△	○	○	○	○	○	○	○	○	○	○	○	○
2008/12/27	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	△	○	○	○
2008/12/28	○	○	○	○	○	○	△	△	△	△	△	△	△	○	△	○	○	○	○	○	○	○	○	○
2008/12/29	○	○	○	○	○	○	△	△	△	△	△	△	△	△	△	△	△	○	○	○	○	○	○	○
2008/12/30	○	○	△	○	○	○	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△
2008/12/31	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△
UT	0h	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	12h	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h



Clear sky ratios at Oma, except summer monsoon season, are around 70%, which are comparable to at Mauna Kea, Hawaii, and much bettre than at Okayama, Japan.

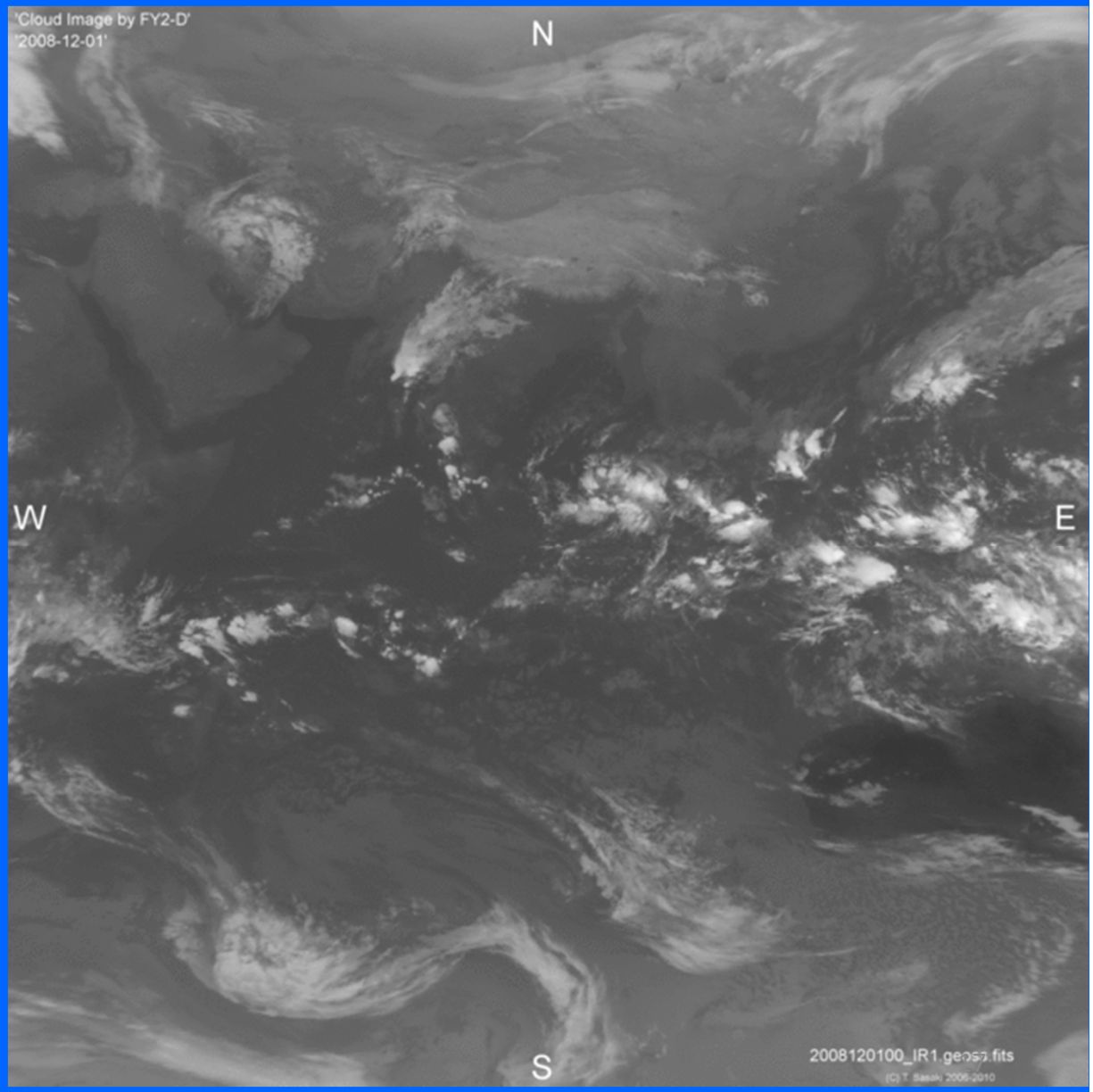
Subaru : statistics during 2000-2010
OAO: summary report during 2008-2009

Weather Satellite, FY2-D, Image

Chinese Weather Satellite, FY2-D, is currently working and their data are available at Chiba-U, Japan on Web site,

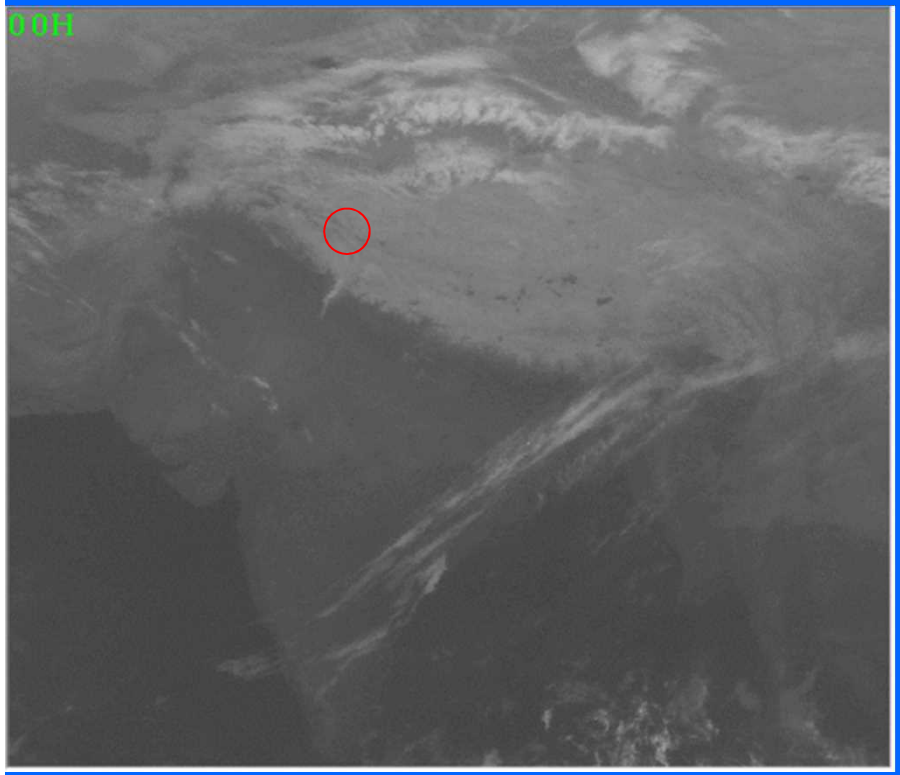
ftp://fy.cr.chiba-u.ac.jp/

(Resolution = 0.04° ～ 4km)

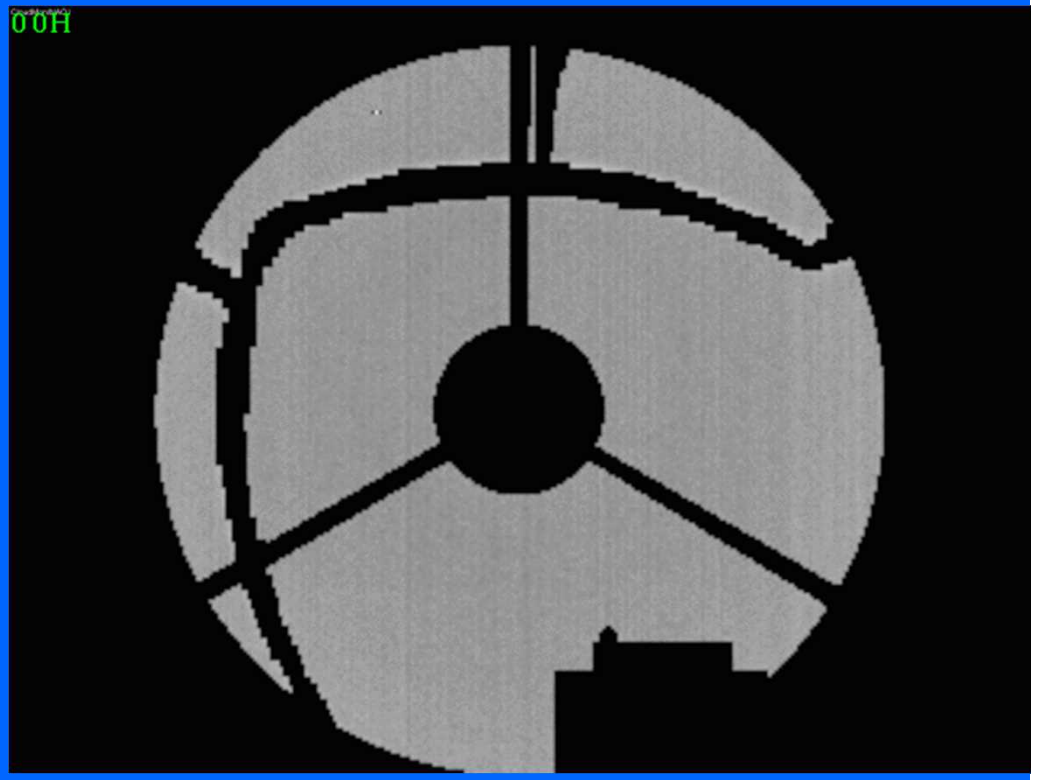


Clouds observed w/Weather Satellite and ground-based CloudMon

Weather Satellite, FY2-D in IR(10μm)

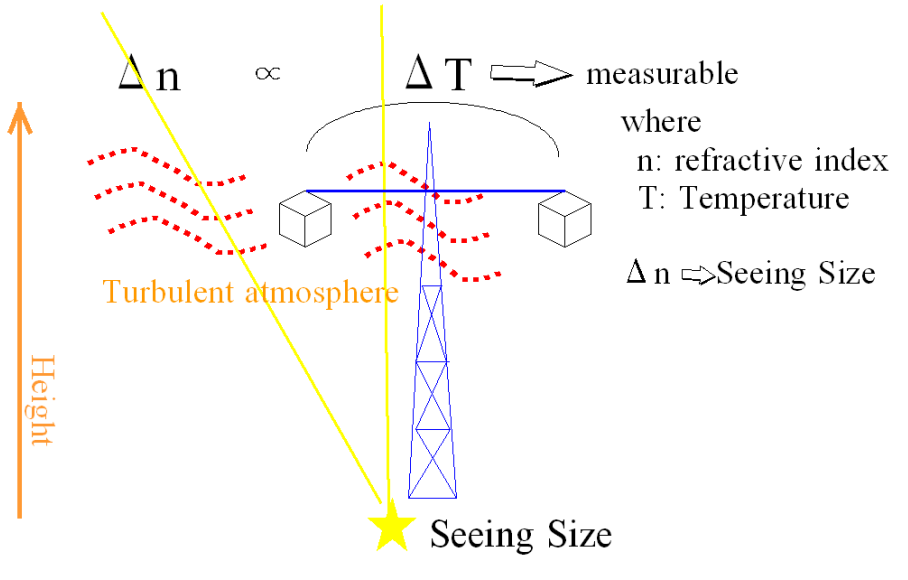


MIR Cloud Monitor Camera (7-14μm)



Ground-based Monitoring of Clouds in the sky is very useful to evaluate the site, as weather satellite data is difficult to clarify localized cloud behaviors.

Micro-thermal turbulence detected with C_T^2 sensors



$$C_T^{\ 2} = \left\langle \left| T(r_1) - T(r_2) \right|^2 \right\rangle r^{-2/3}$$

C_T^2 : temperature structure coefficient

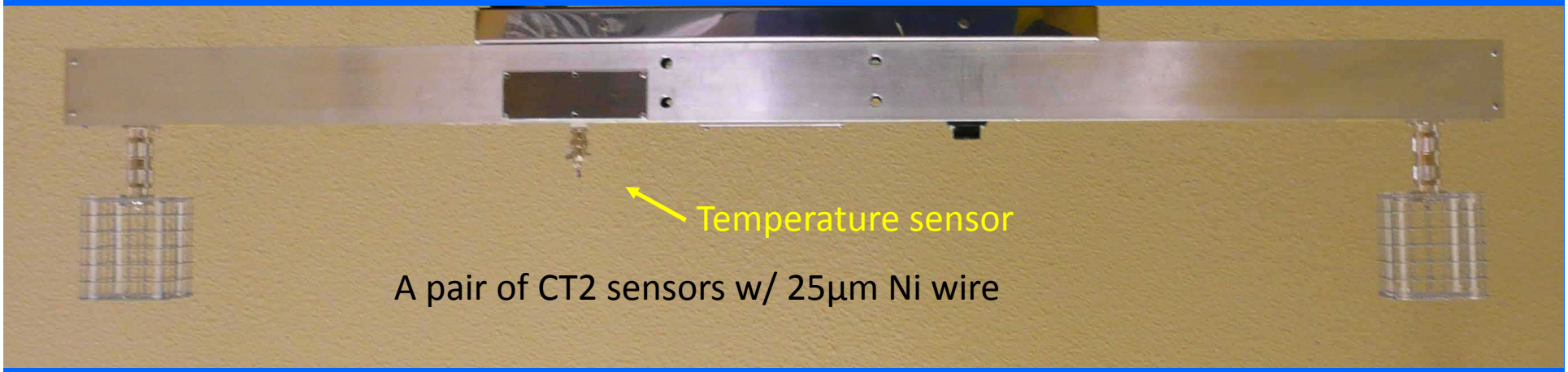
$$C_n^{\ 2} \propto P^2\, T^{-4}\, C_T^{\ 2}$$

C_n^2 : refractive index structure coefficient

Related Site testing instruments

- DIMM: Differential Image Motion Monitor
- MASS/SCIDAR: Multi Aperture Scintillation Sensor
- C_T^2 sensor : Micro-thermal turbulence in surface layer to measure height variation
- SNODAR: Surface layer Non-Doppler Acoustic Radar to measure Scintillation
- SODAR: Sound detection and ranging to measure Scintillation

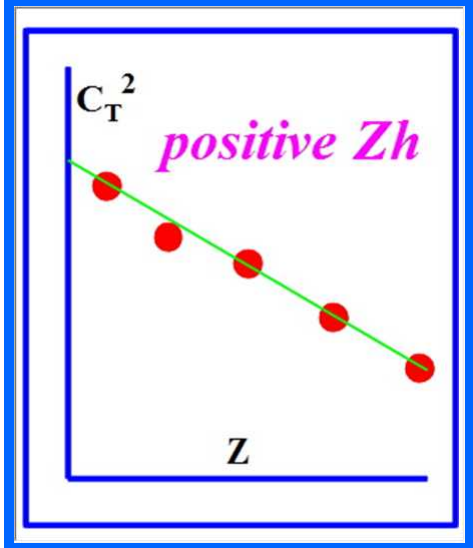
CT2 measurements at Karasu and at Oma



A pair of CT2 sensors w/ 25μm Ni wire

Temperature Structure Coefficient

$$C_T^2(z) = C_T^2(z_0)\exp(-(z-z_0)/z_h)$$



$$C_T^2 = \left\langle \left| T(r_1) - T(r_2) \right|^2 \right\rangle r^{-2/3}$$

Image deterioration estimated from C_T^2

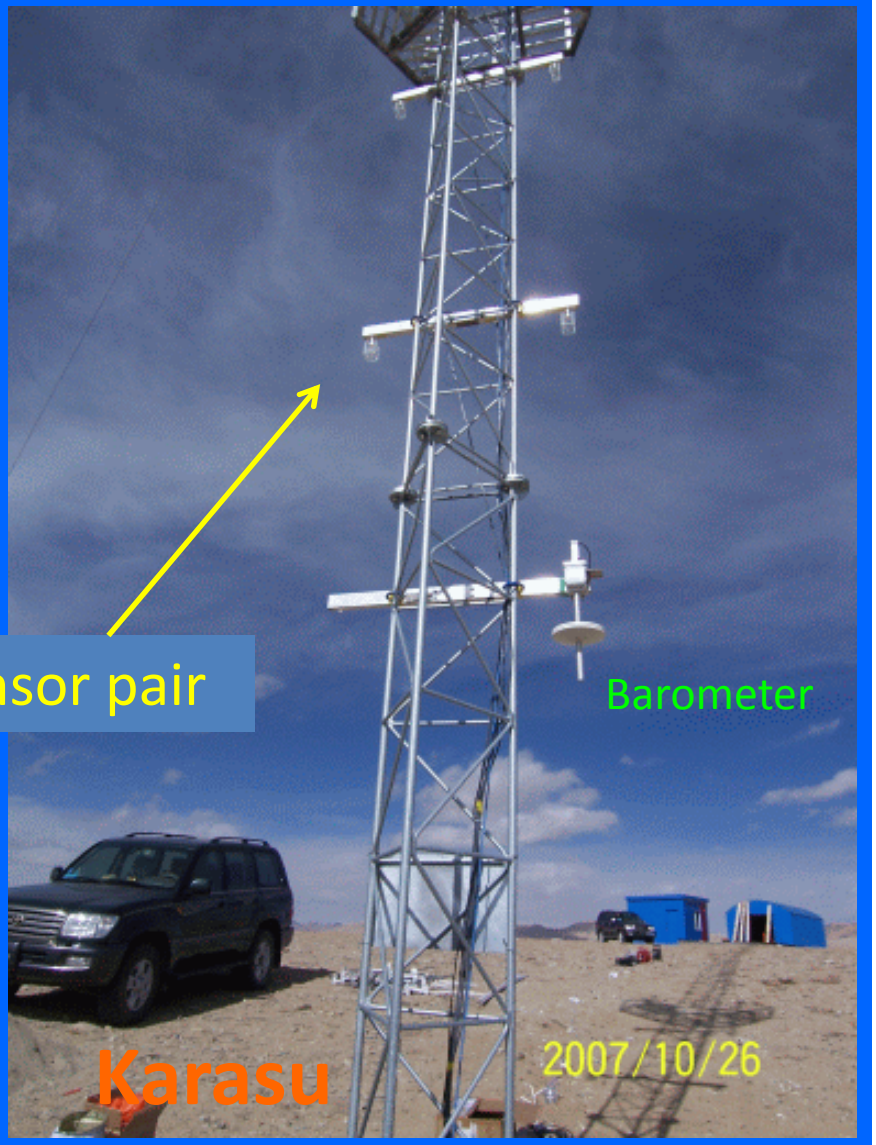
$$\theta(z) = 5.3\lambda^{-1/5}\left(\frac{7.9\times10^{-5}P}{T^2}\right)^{6/5}\left[C_T^2(z)z_h\right]^{3/5}$$

C_T^2 measurements at Karasu and at Oma

5 Layers of a C_T^2 sensor pair

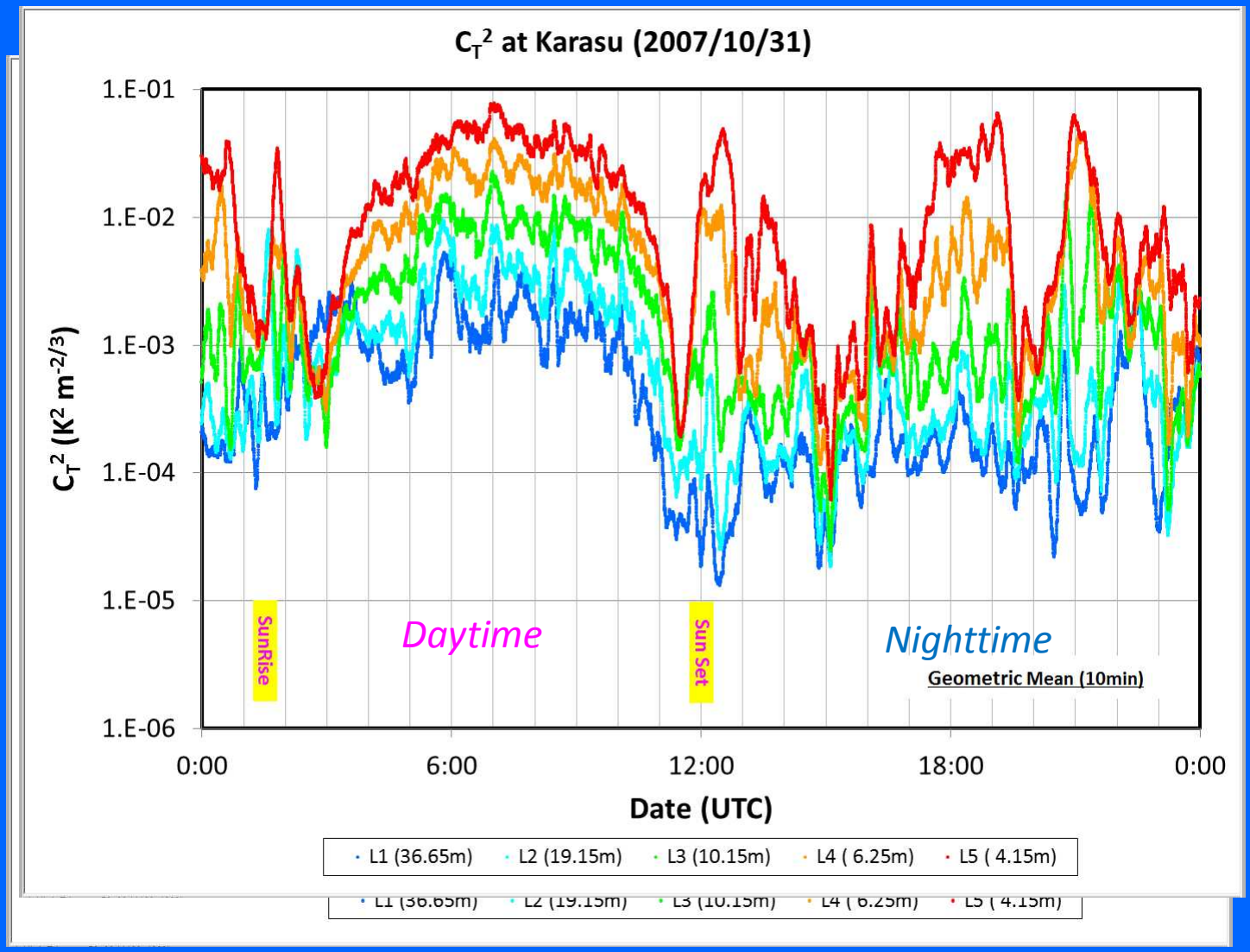
Barometer

Controller and
Digital Multimeter



Micro-thermal turbulence detected with C_T^2 sensors

at Karasu



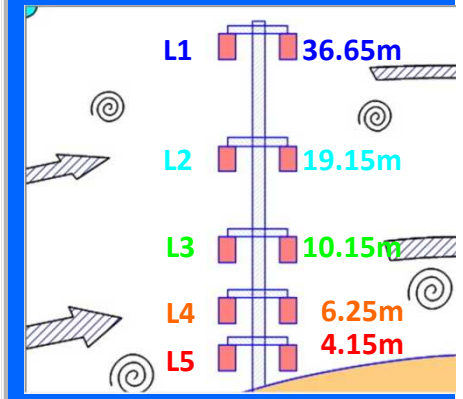
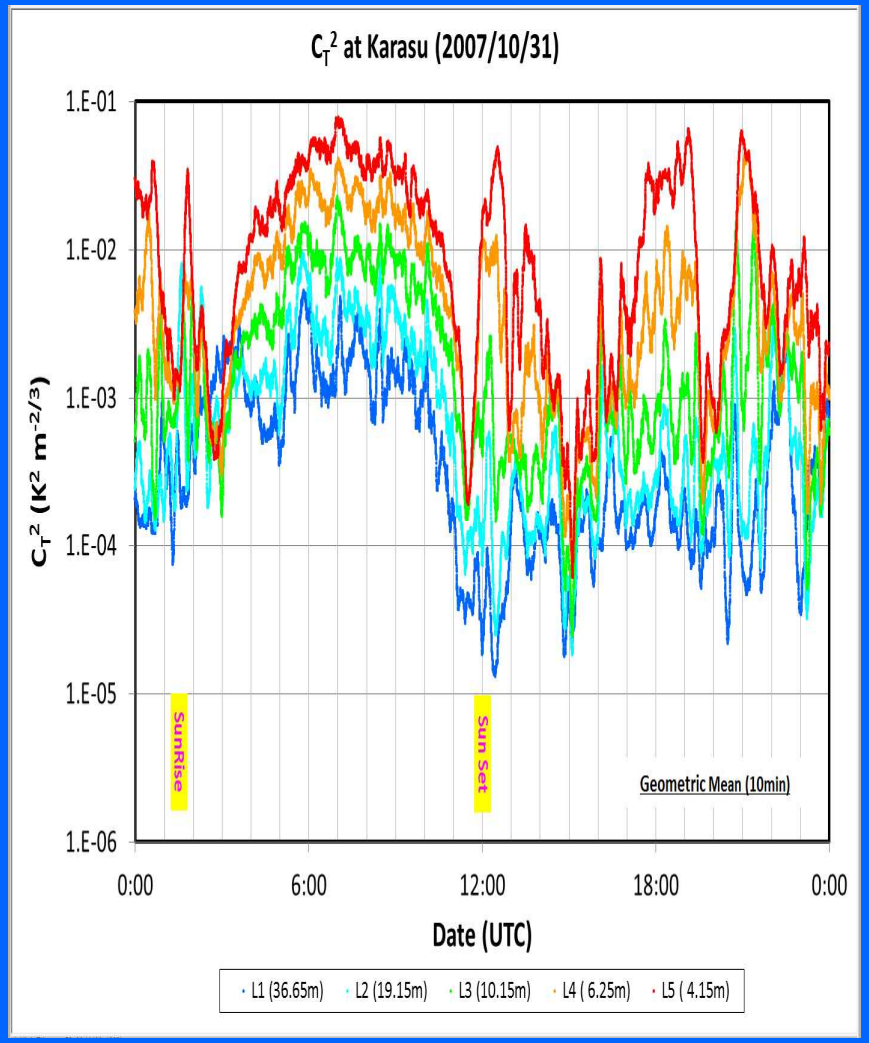
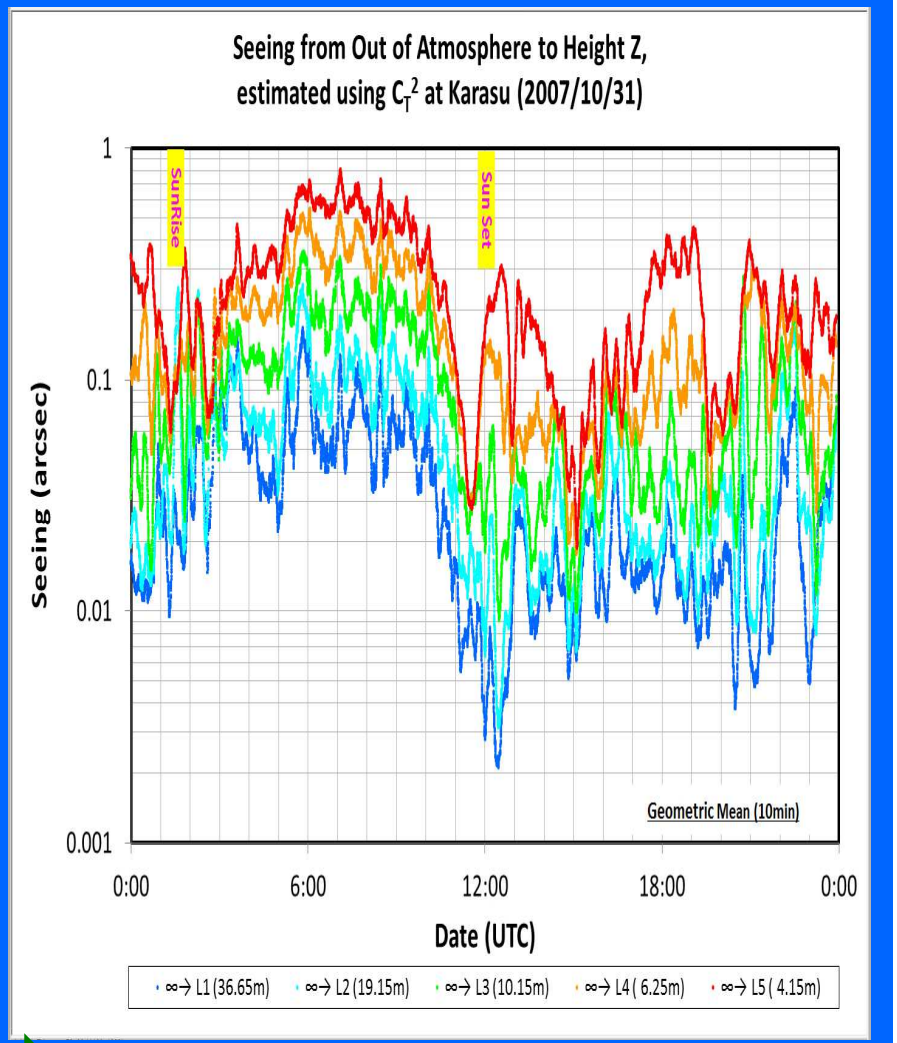


Image deterioration estimated with C_T^2 data





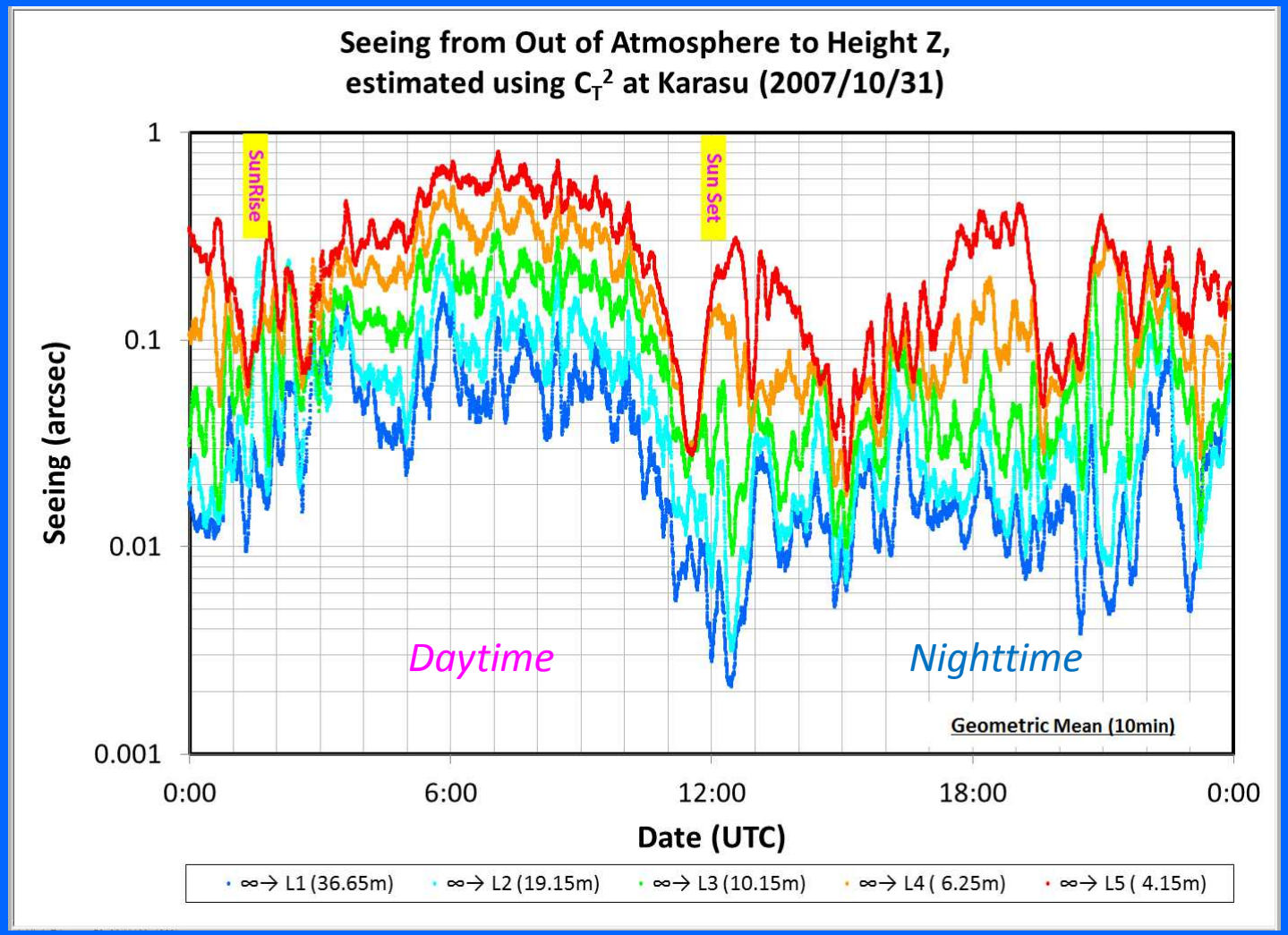
C_T^2 distribution

$$\theta(z) = 5.3\lambda^{-1/5}\left(\frac{7.9\times10^{-5}P}{T^2}\right)^{6/5}\left[C_T^{\,2}(z)z_h\right]^{3/5}$$

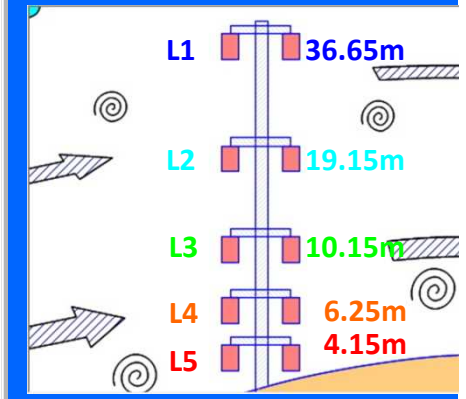
Image deterioration derived from C_T^2 distribution

at Karasu

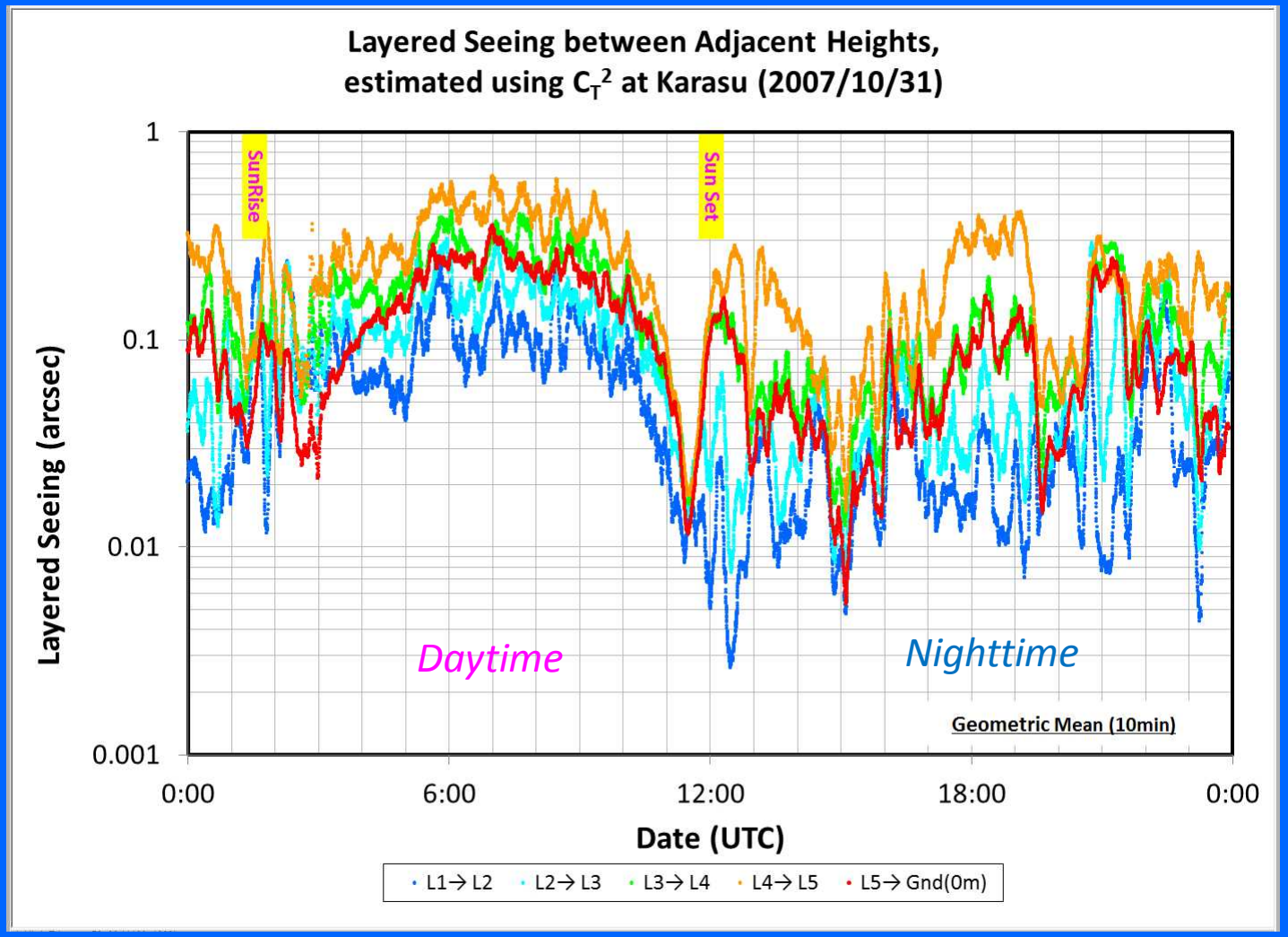
Image deterioration estimated with C_T^2 data



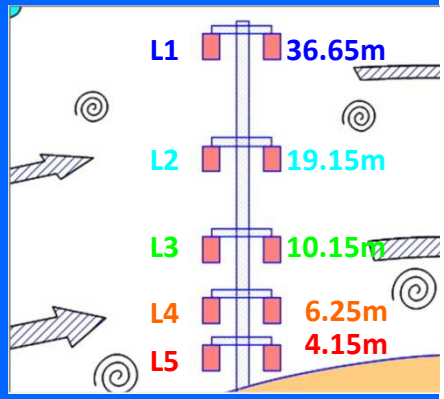
at Karasu



Layered Image deterioration estimated with C_T^2 data



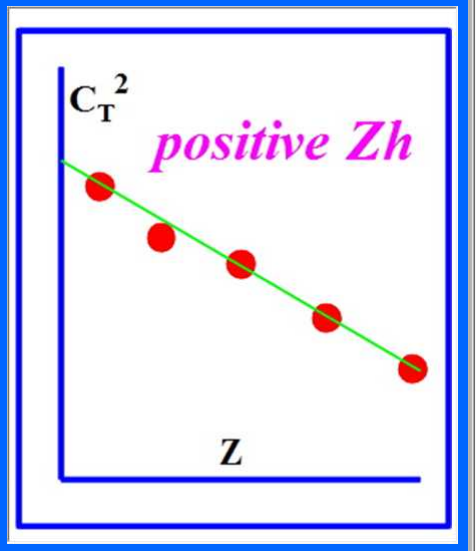
at Karasu

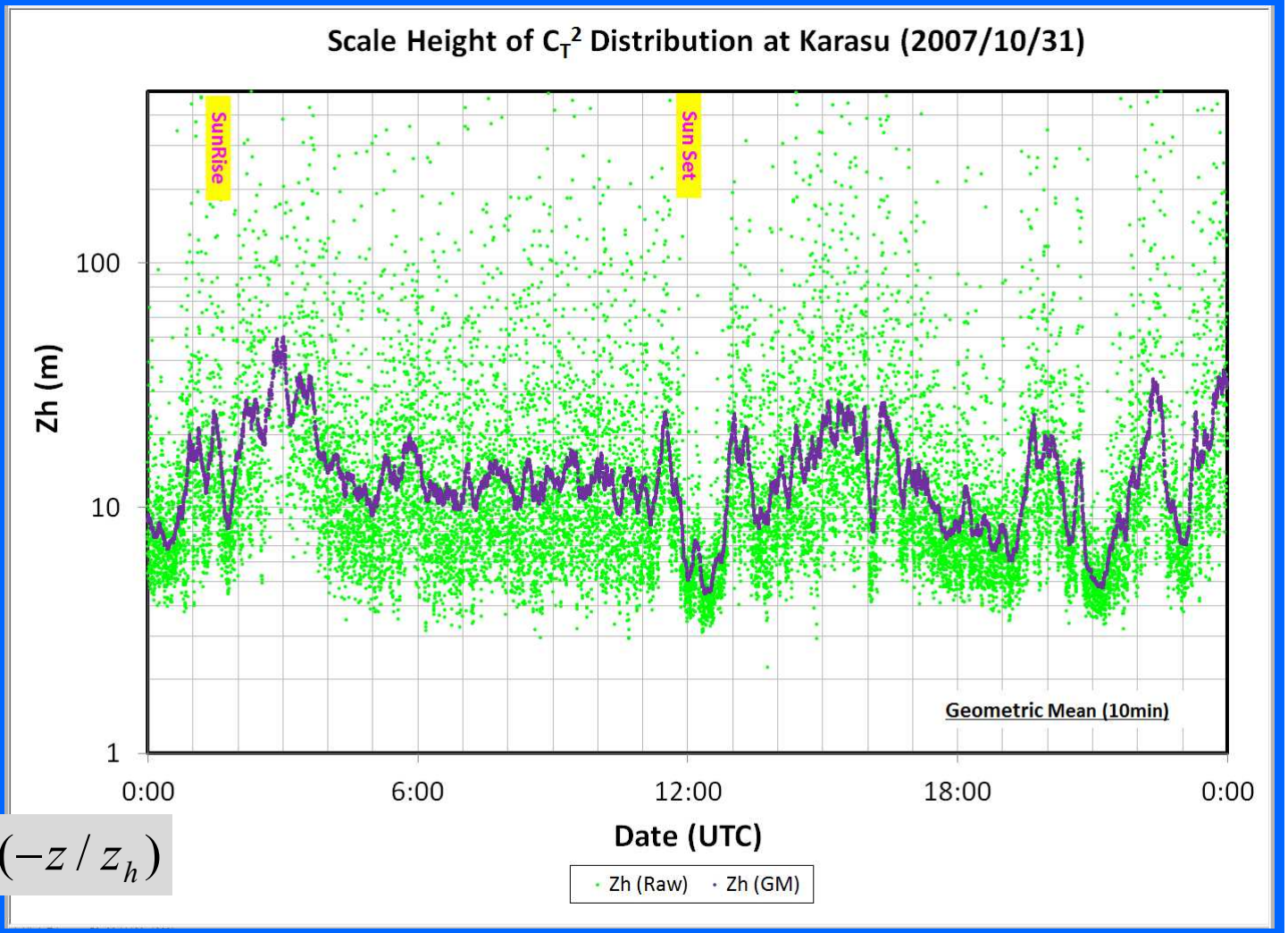


Local Image deterioration between heights of z1 and z0

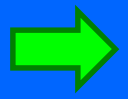
$$\theta(z_1 : z_0) = \left(\theta(z_1)^{5/3} - \theta(z_0)^{5/3}\right)^{3/5}$$

Scale Height of vertical distribution of C_T^2 data





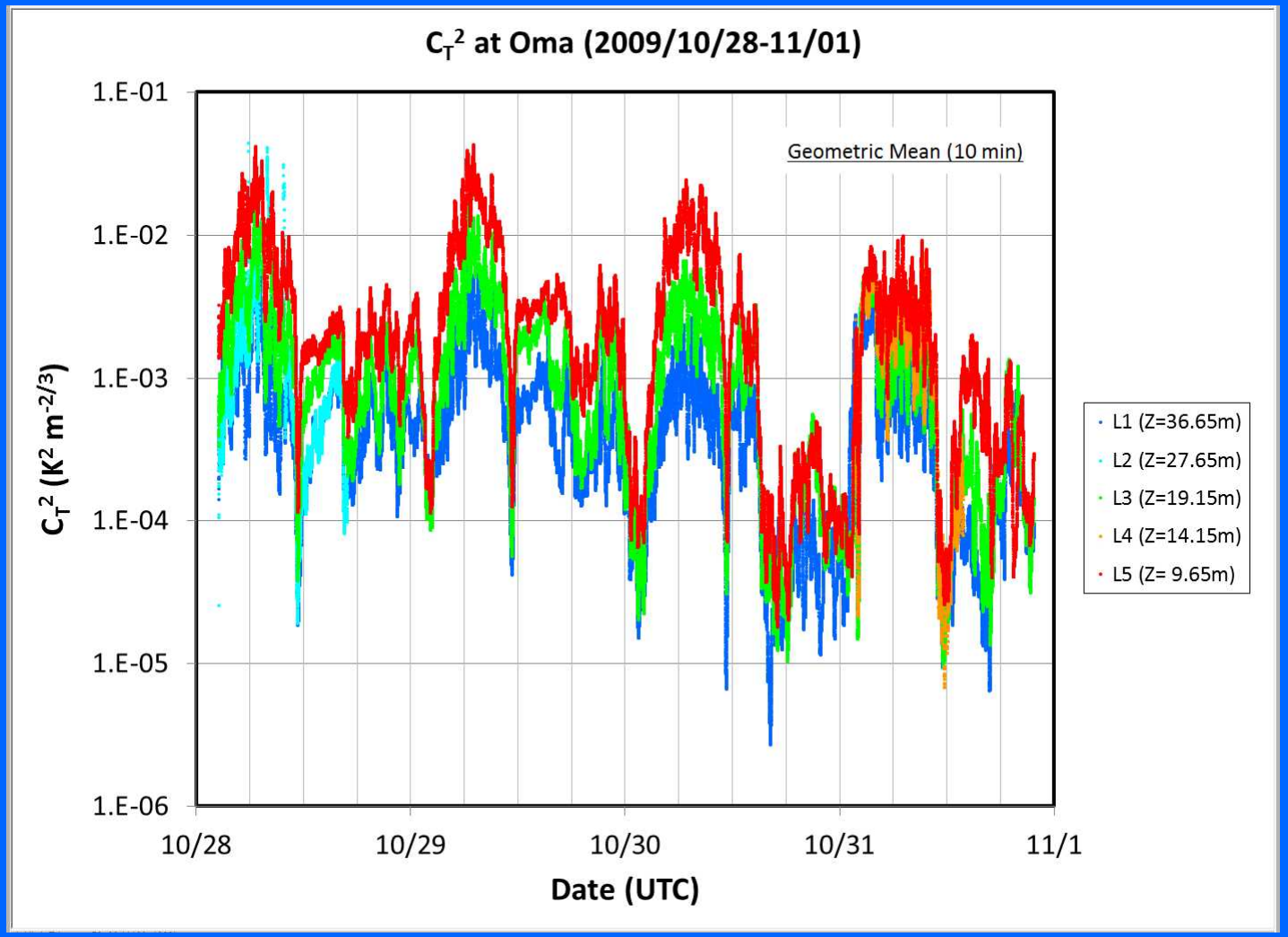
$$C_T^{\ 2}(z) = C_T^{\ 2}(0)\exp(-z/z_h)$$



derive Z_h

at Karasu

Micro-thermal turbulence detected with C_T^2 sensors



at Oma

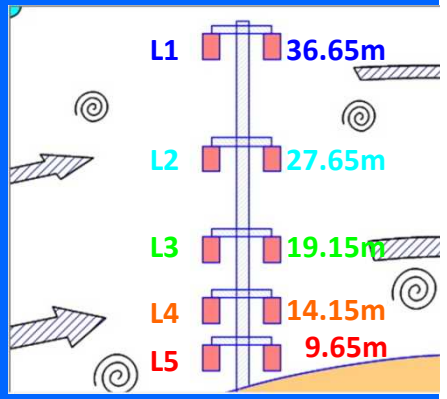
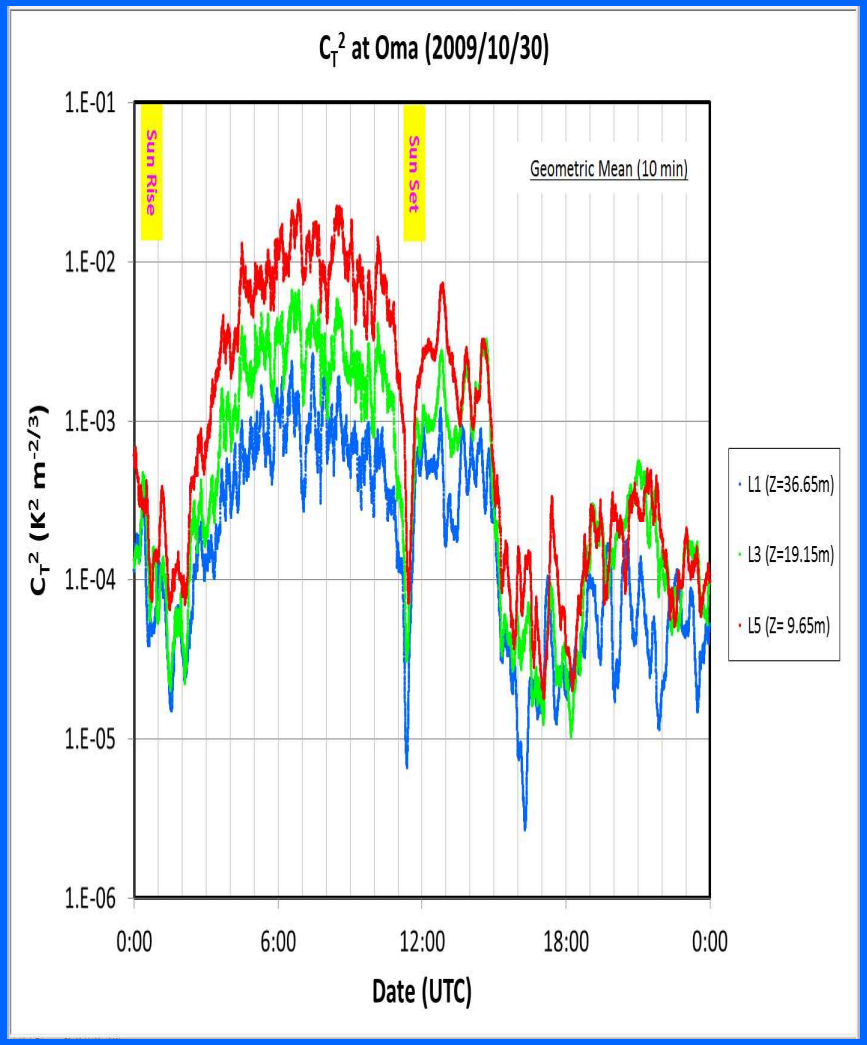


Image deterioration estimated with C_T^2 data



CT2 distribution

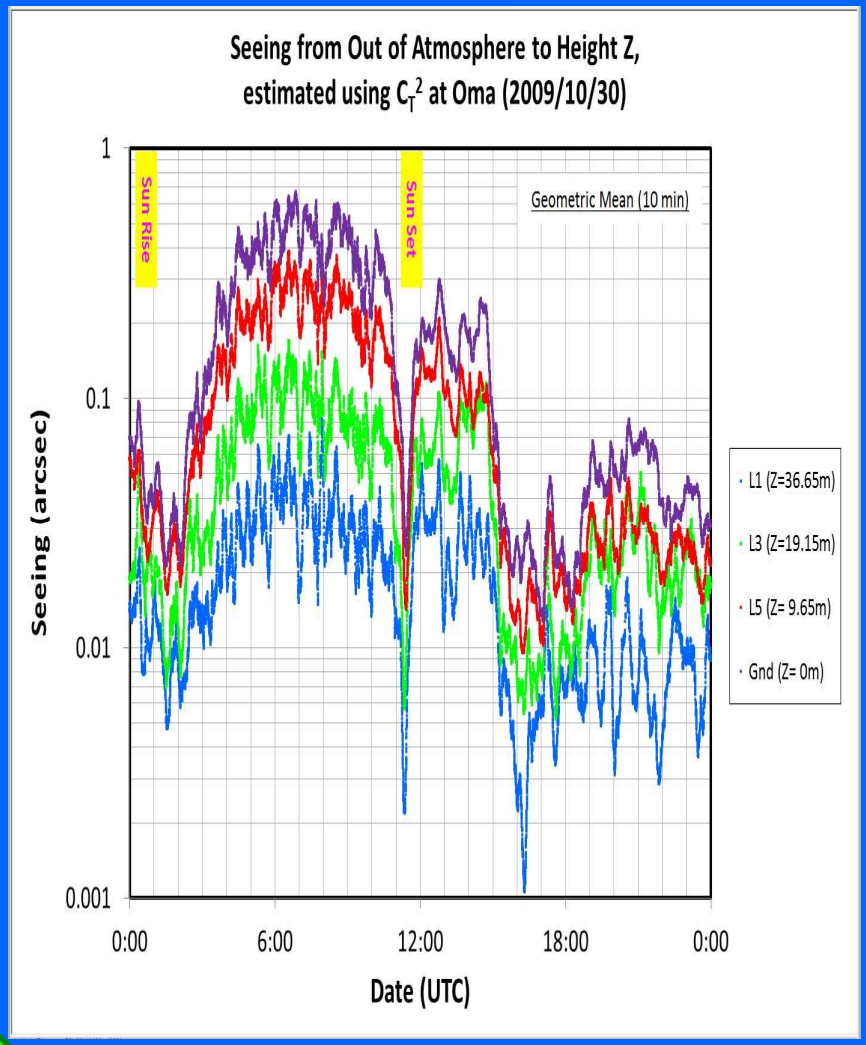
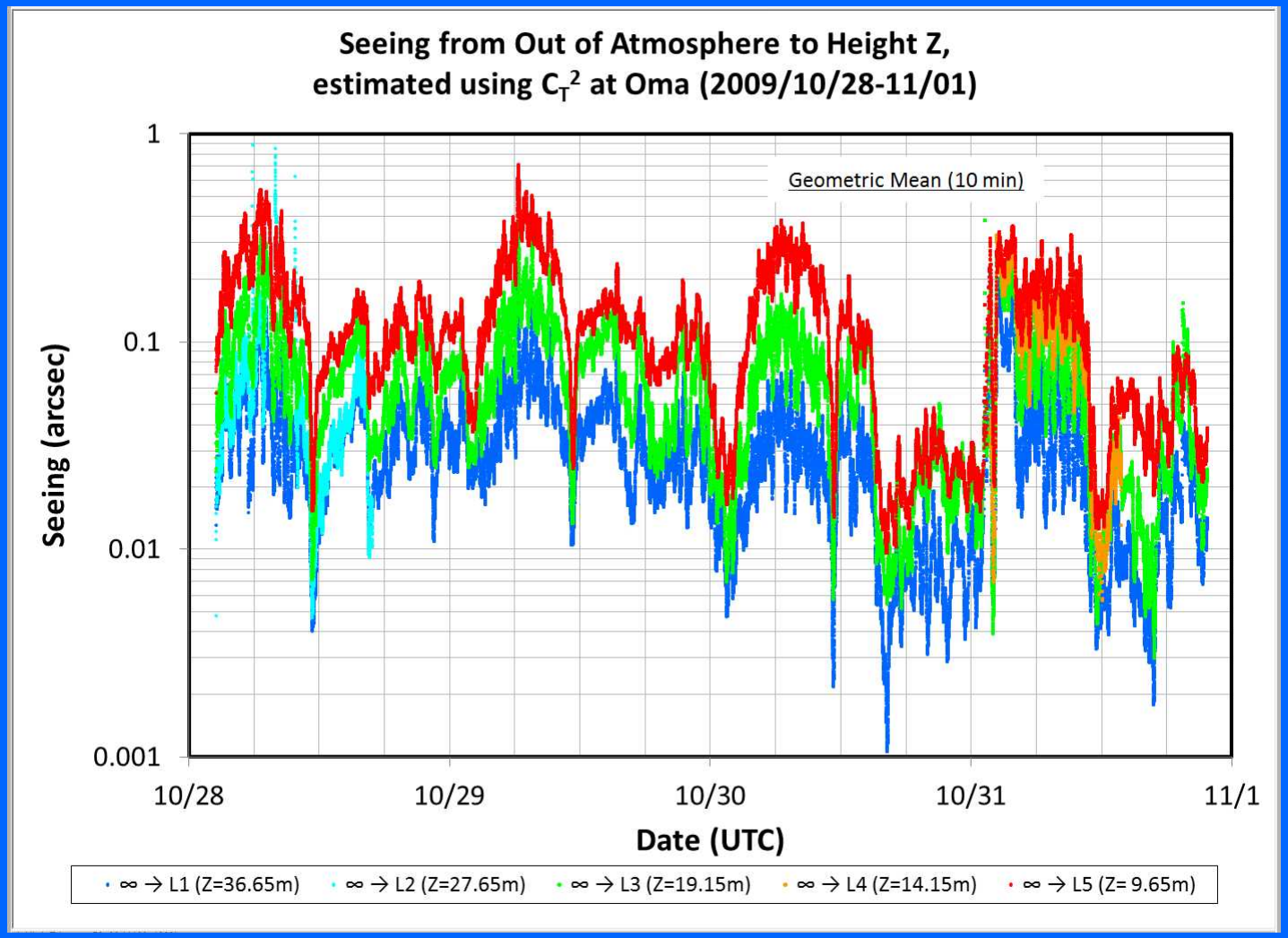


Image deterioration derived from CT2 distribution

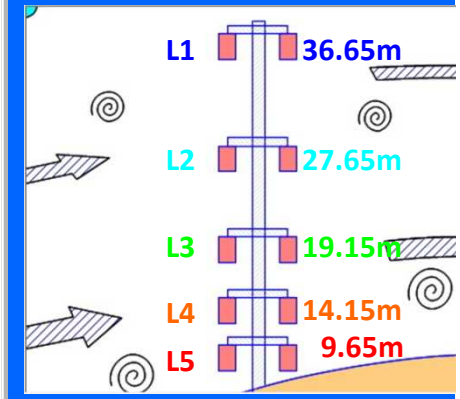
$$\theta(z) = 5.3\lambda^{-1/5}\left(\frac{7.9\times10^{-5}P}{T^2}\right)^{6/5}\left[C_T{}^2(z)z_h\right]^{3/5}$$

at Oma

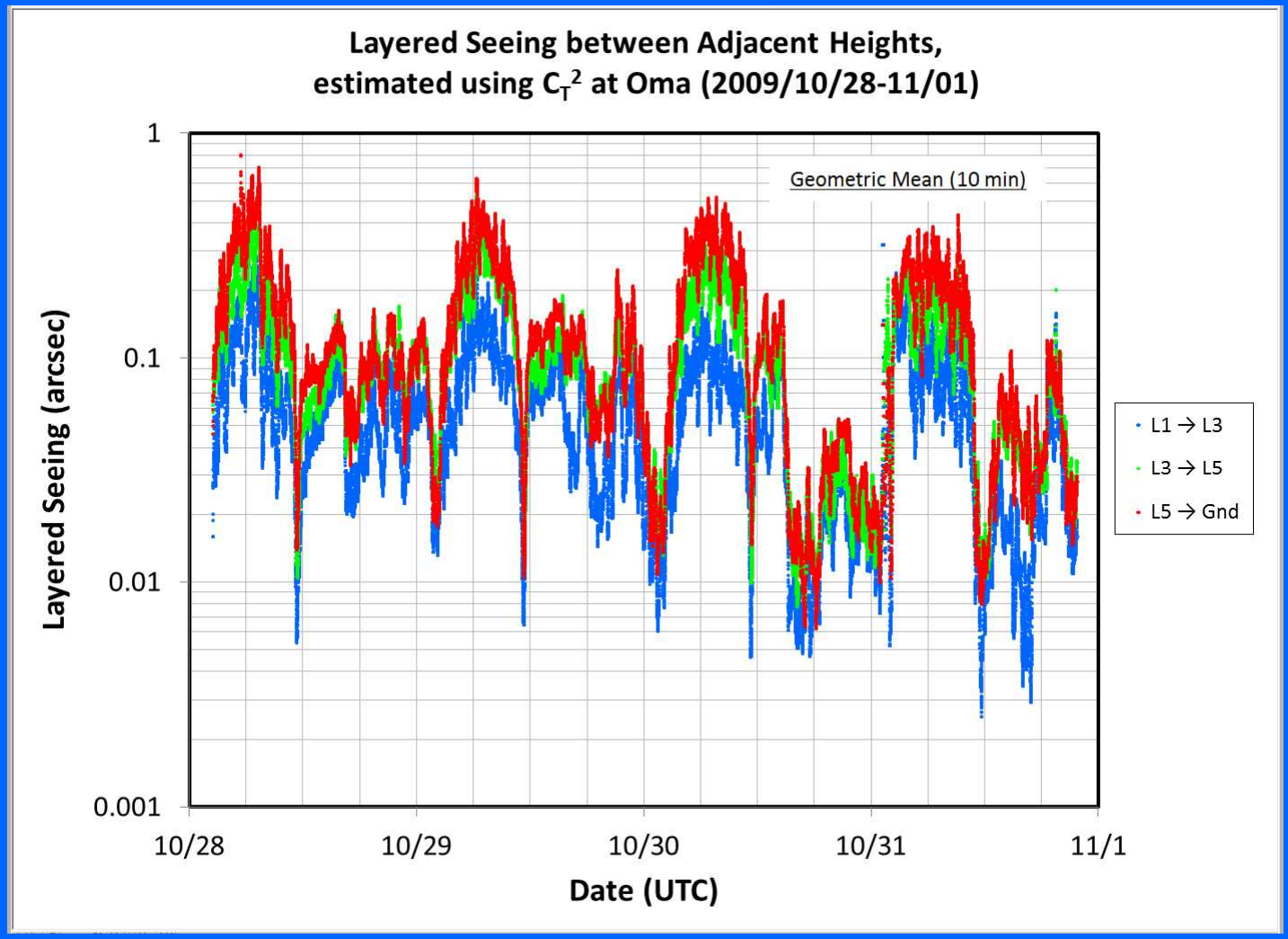
Image deterioration estimated with C_T^2 data

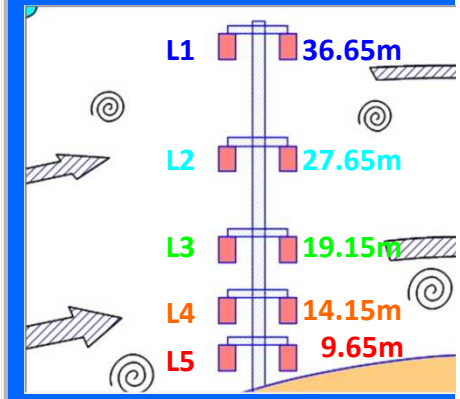


at Oma

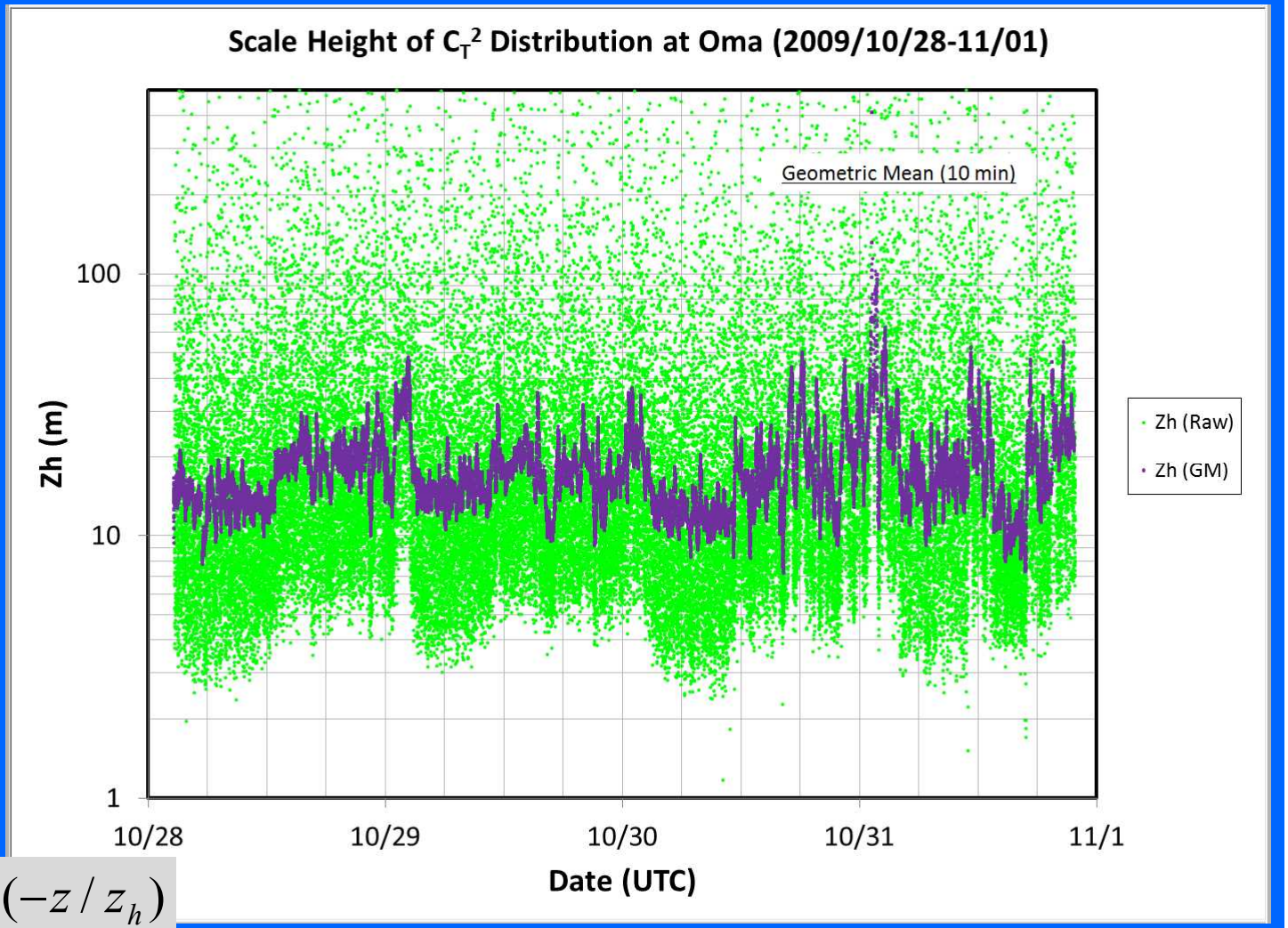


Layered Image deterioration estimated with C_T^2 data at Oma





Scale Height of vertical distribution of C_T^2 data

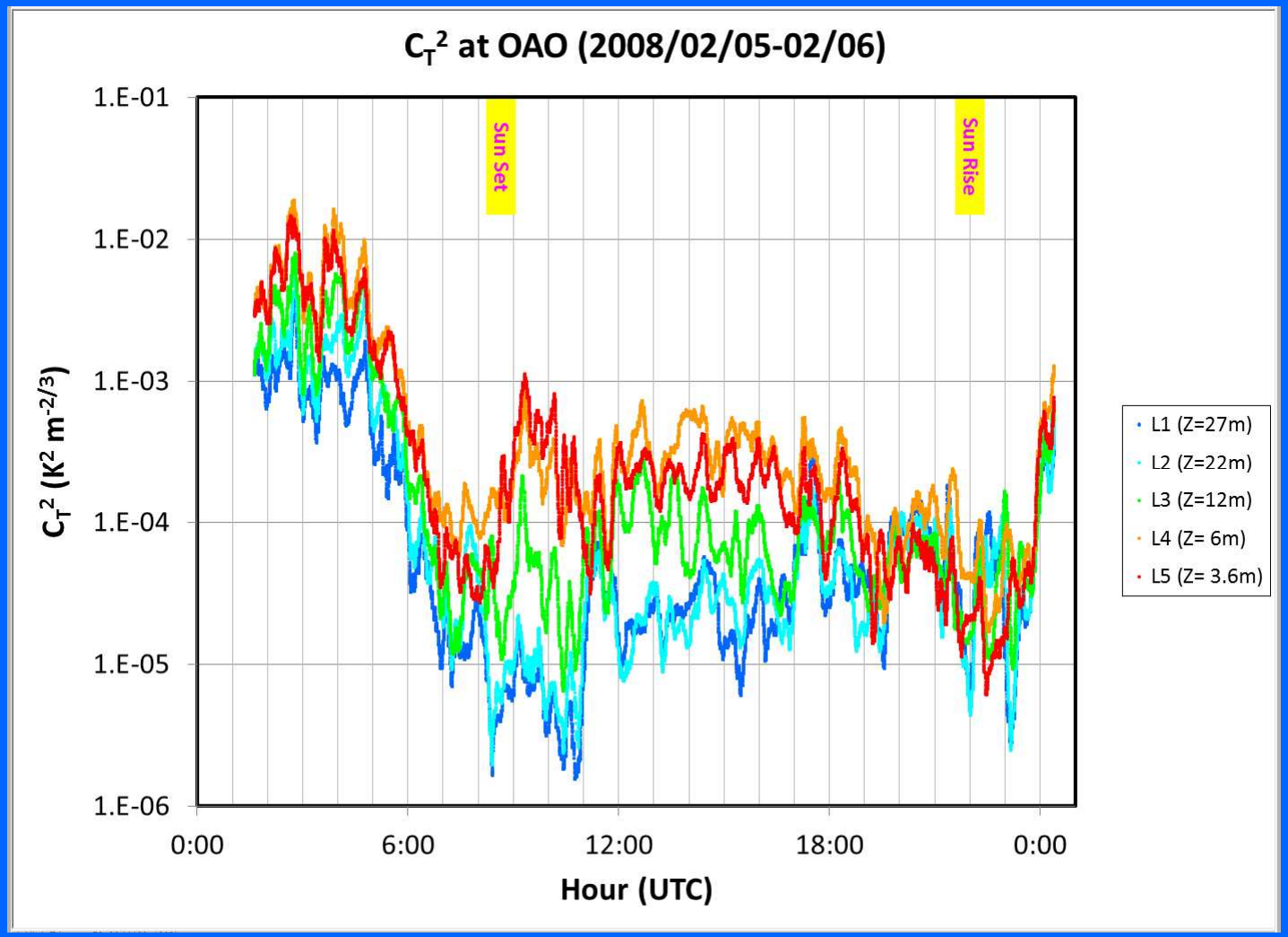


$$C_T^{\ 2}(z) = C_T^{\ 2}(0)\exp(-z/z_h)$$

derive Z_h

at Oma

Micro-thermal turbulence detected with C_T^2 sensors



at OAO (Japan)

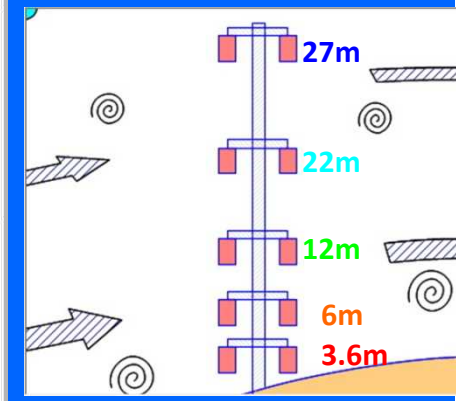
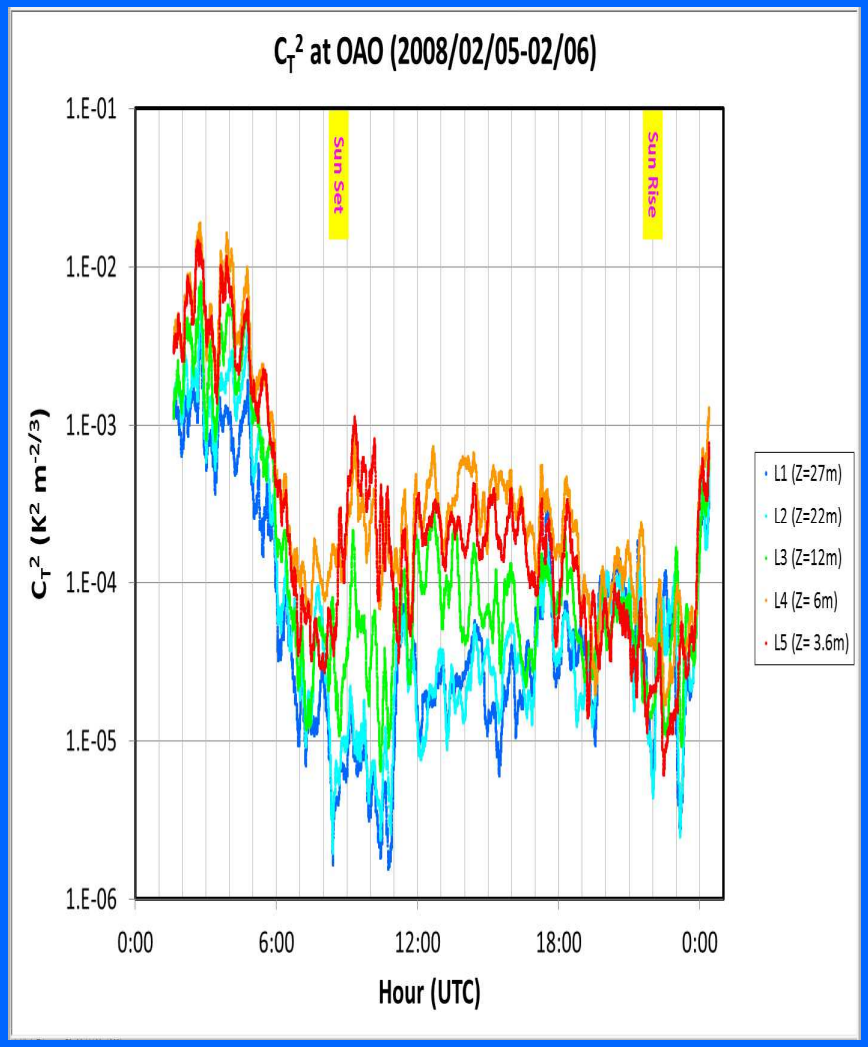


Image deterioration estimated with C_T^2 data



CT2 distribution

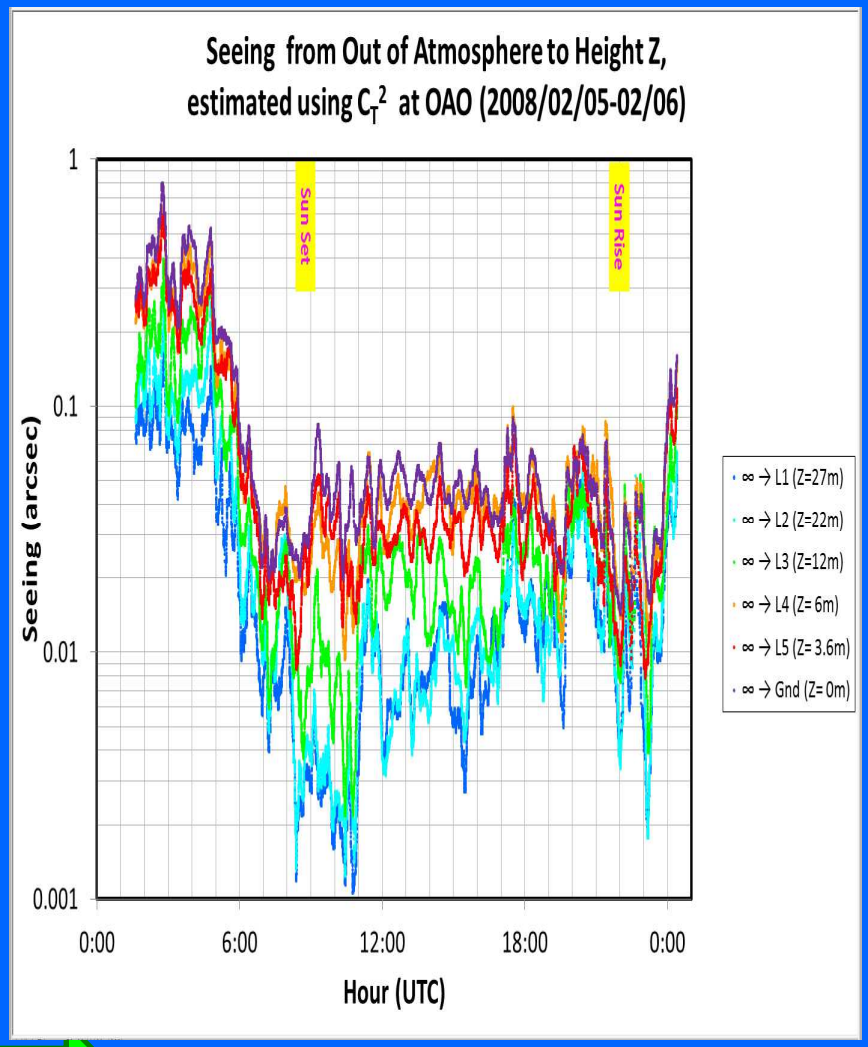
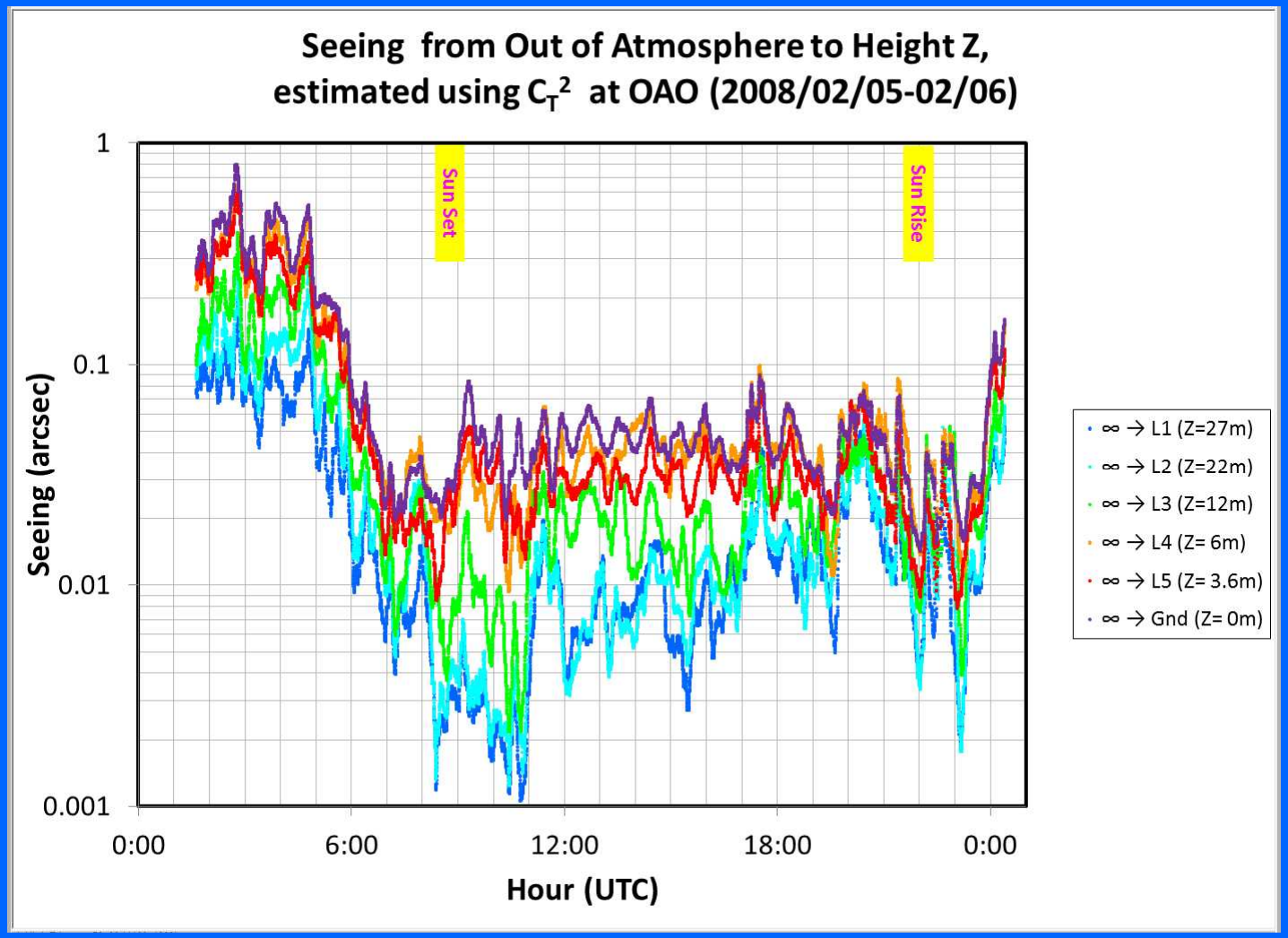


Image deterioration derived from CT2 distribution

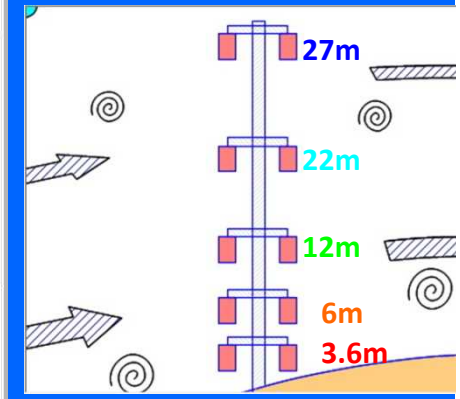
$$\theta(z) = 5.3\lambda^{-1/5}\left(\frac{7.9\times10^{-5}P}{T^2}\right)^{6/5}\left[C_T{}^2(z)z_h\right]^{3/5}$$

at OAO (Japan)

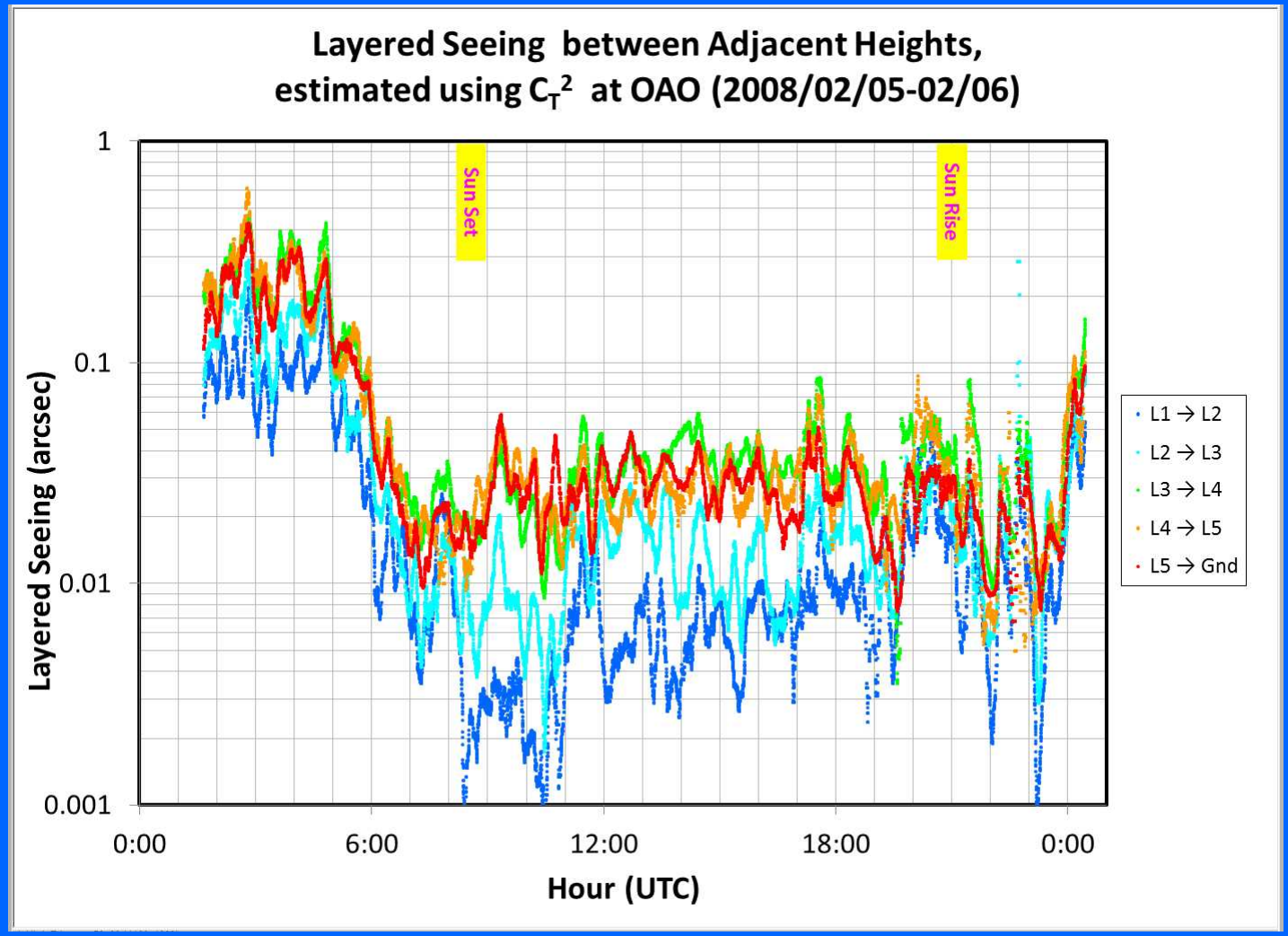
Image deterioration estimated with C_T^2 data



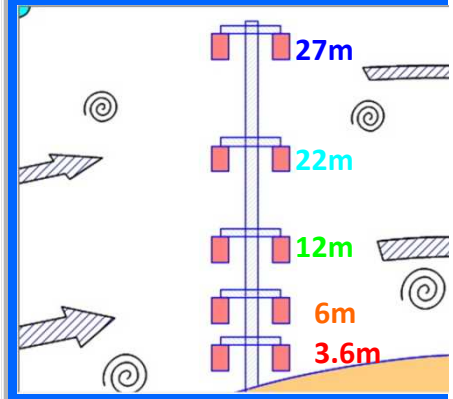
at OAO (Japan)



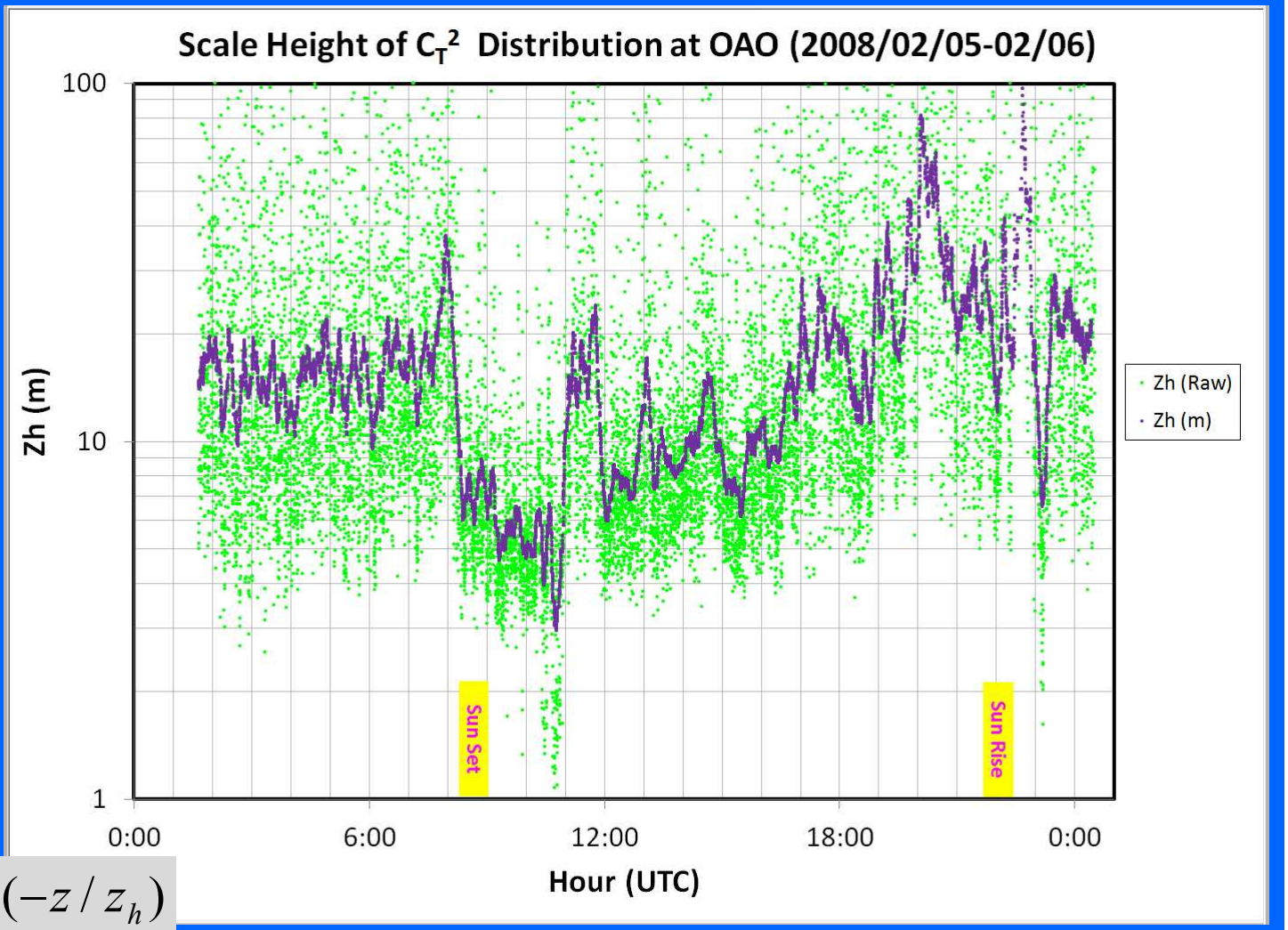
Layered Image deterioration estimated with C_T^2 data



at OAO (Japan)



Scale Height of vertical distribution of C_T^2 data

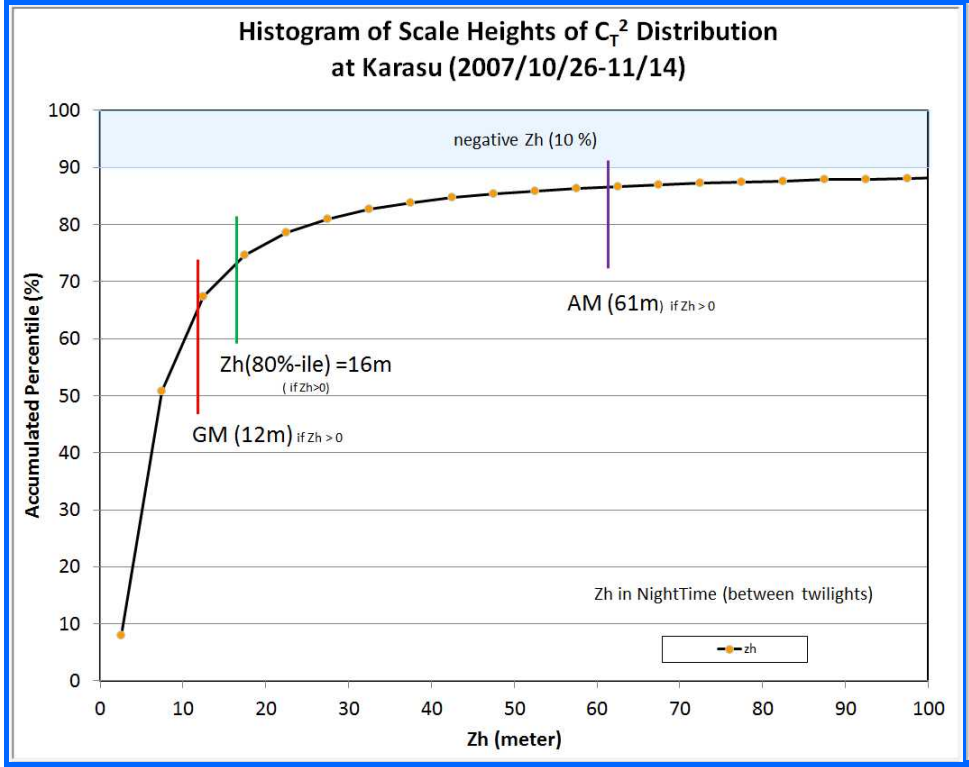


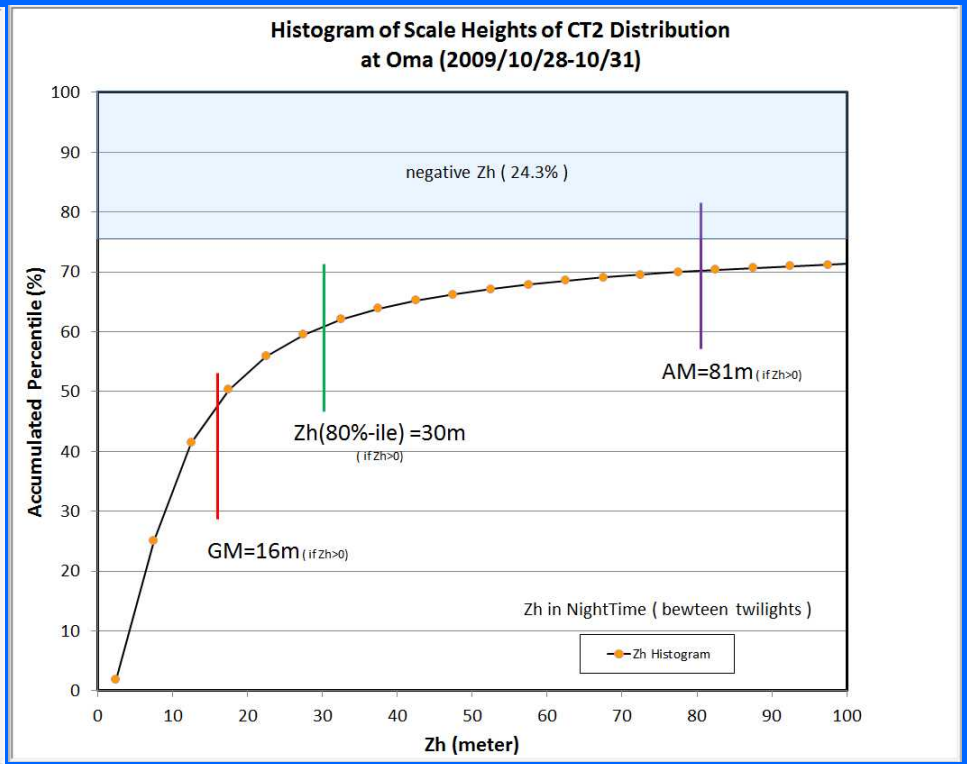
$$C_T^{\ 2}(z) = C_T^{\ 2}(0)\exp(-z/z_h)$$

derive Z_h

at OAO (Japan)

Histogram of scale height, Z_h , of vertical C_T^2 distribution





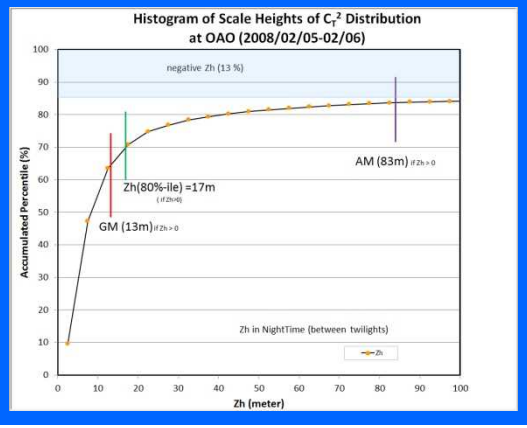
at Karasu

CT2Karasu_20071026UT07H_20071115UT01_Seeing_10min_1.xlsx

CT2Okayama_20080205UT01H_20080206UT00H_Seeing_10min_1.xlsx

at Oma

CT2Oma_20091028UT02H_20091111UT10H_Seeing_10min_1.xlsx

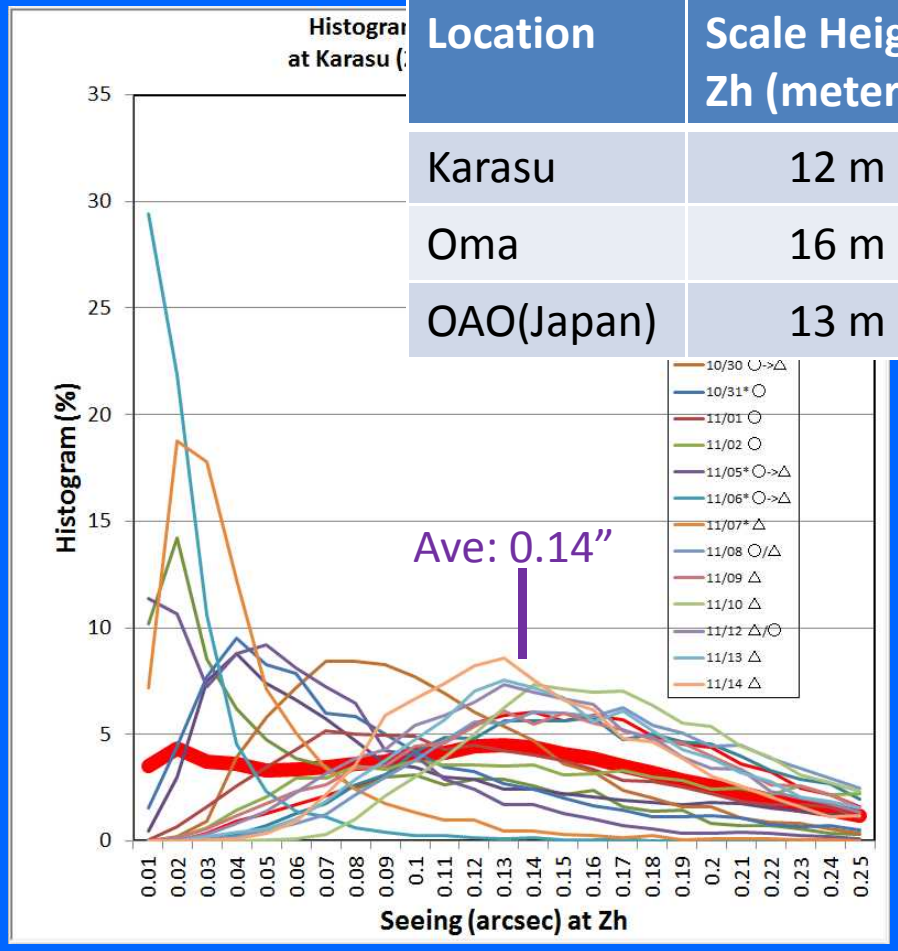


at OAO (Japan)

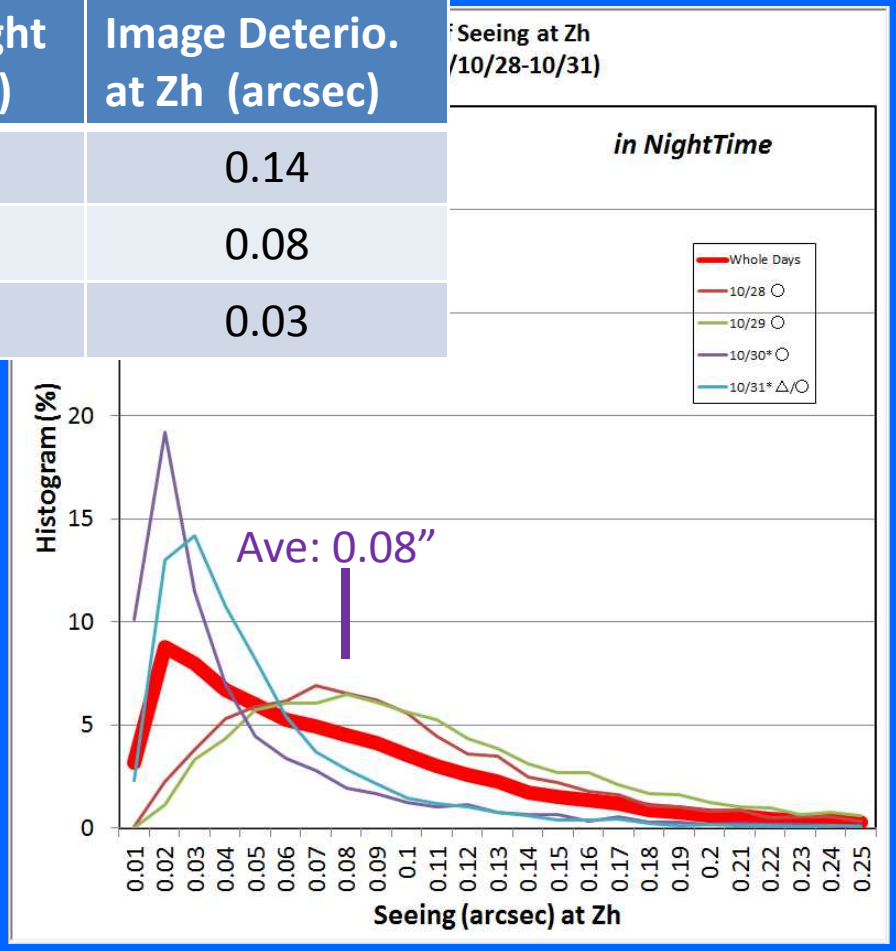
Location	GM of Scale Height Zh (meter)	Z of 80%-ile (for Zh>0)
Karasu	12 m	16m (@72%)
Oma	16 m	30m (@61%)
OAO (Japan)	13 m	17m (@70%)

Histogram of image deterioration at Z_h estimated from C_T^2

Location	Scale Height Zh (meter)	Image Deterio. at Zh (arcsec)
Karasu	12 m	0.14
Oma	16 m	0.08
OAO(Japan)	13 m	0.03

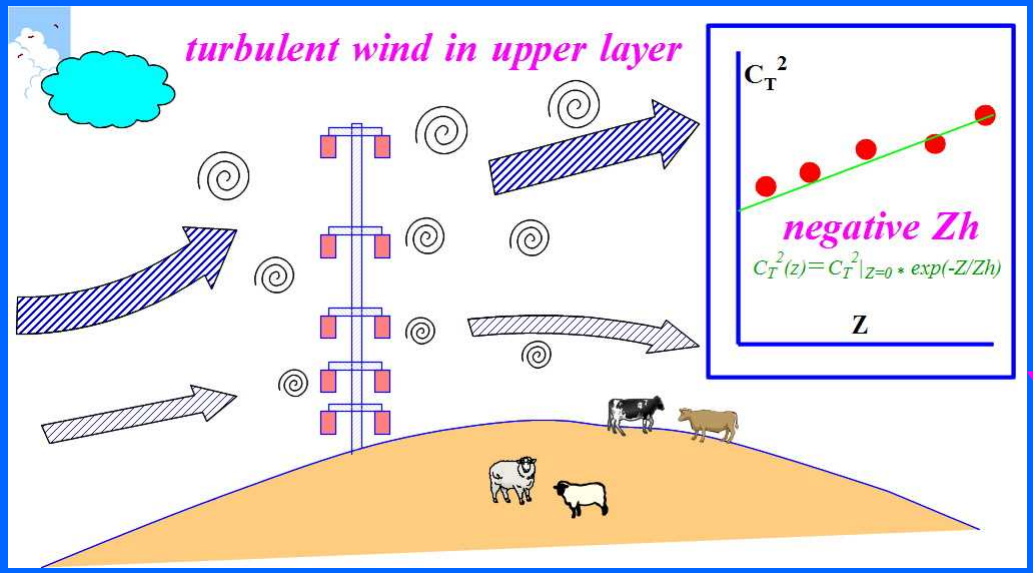


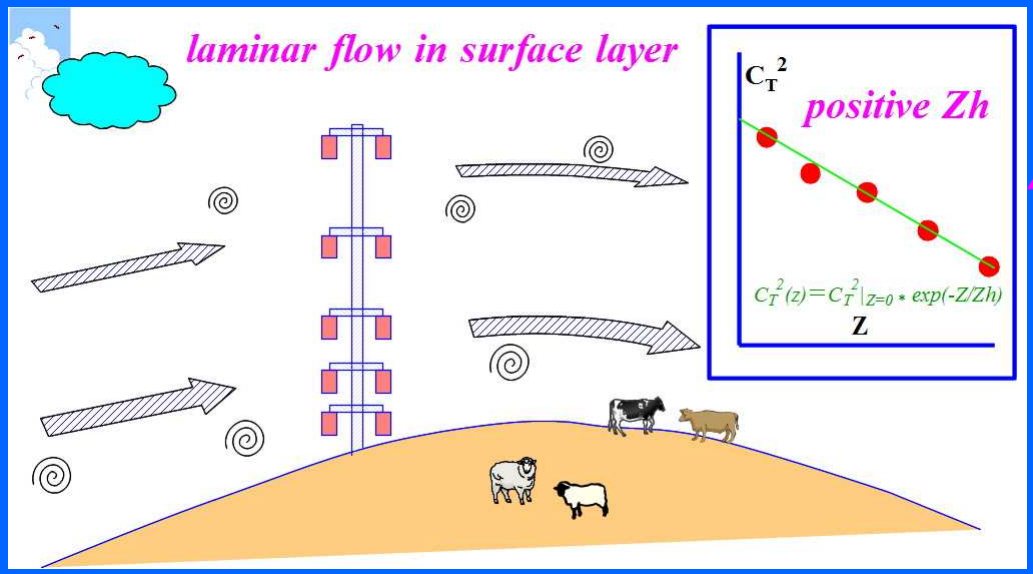
at Karasu CT2Karasu_20071026UT07H_20071115UT01_Seeing_10min_1.xlsx



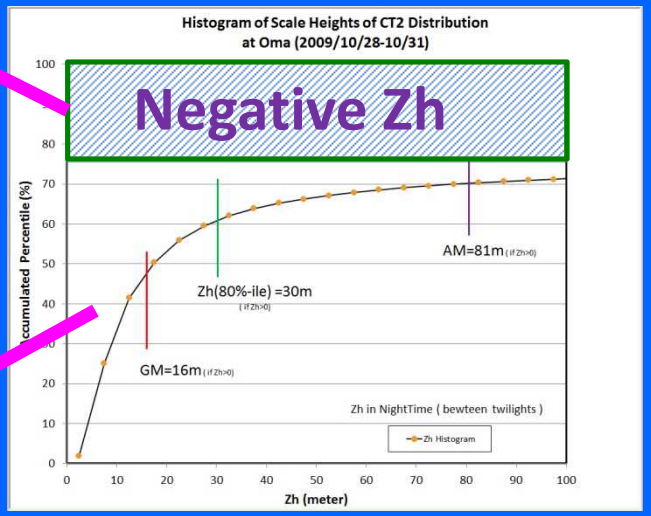
at Oma CT2Oma_20091028UT02H_20091111UT10H_Seeing_10min_1.xlsx

Negative Zh means higher turbulent atmosphere caused by strong wind





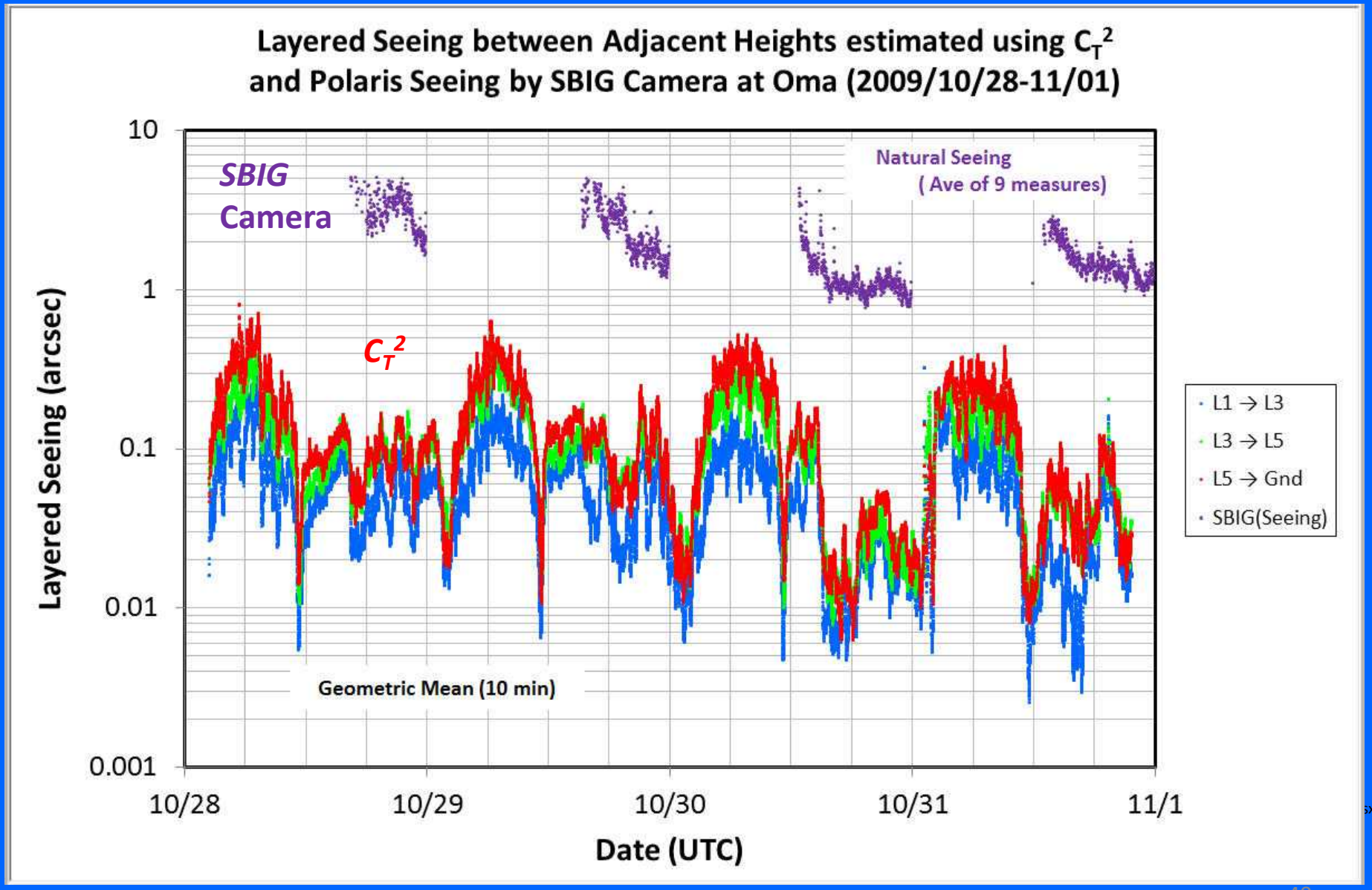
at Oma



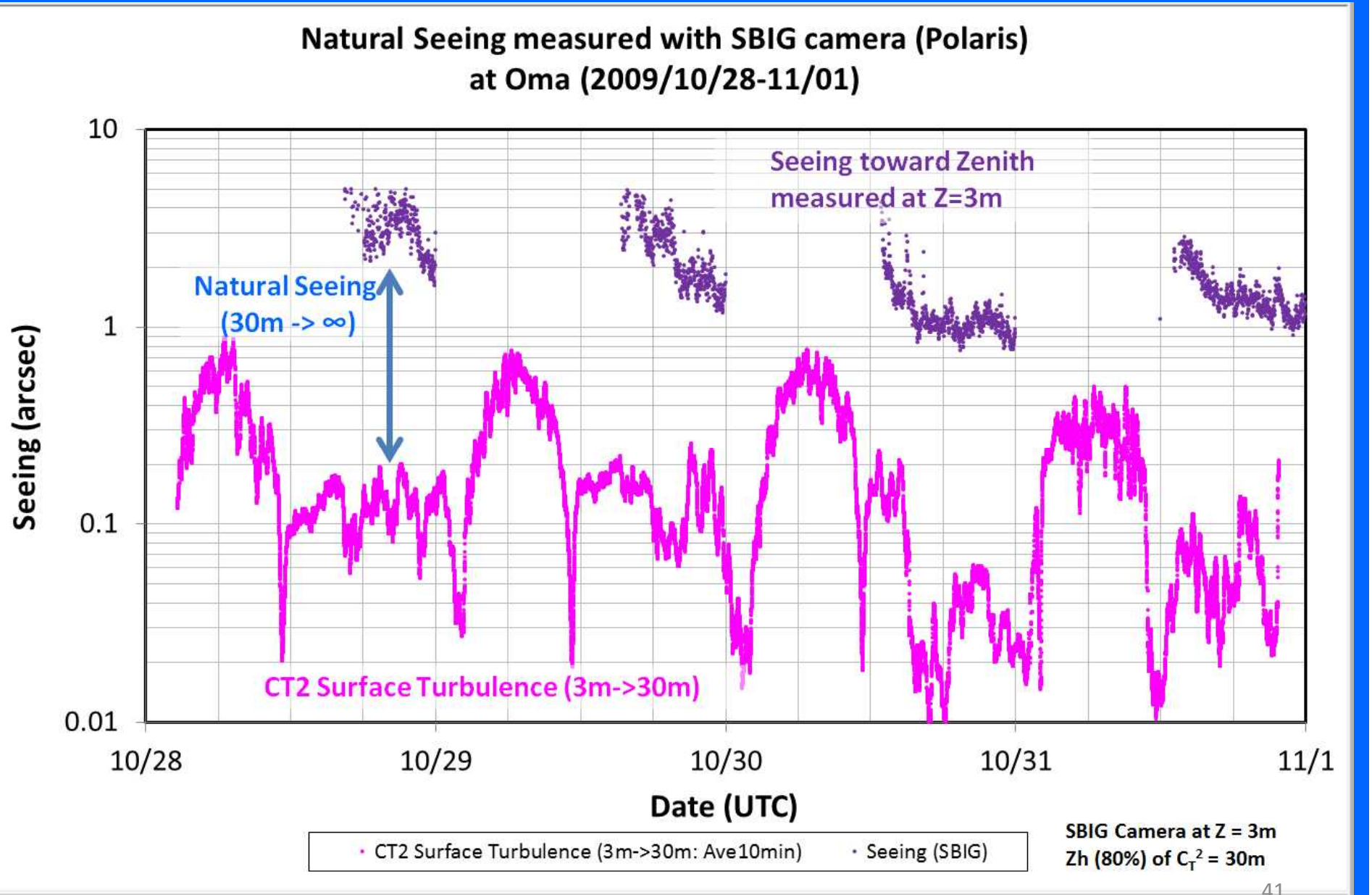
CT2Oma_20091028UT02H_20091111UT10H_Seeing_10min_1.xlsx

Upper atmosphere should be measured on turbulent motions with SNODAR (planned).

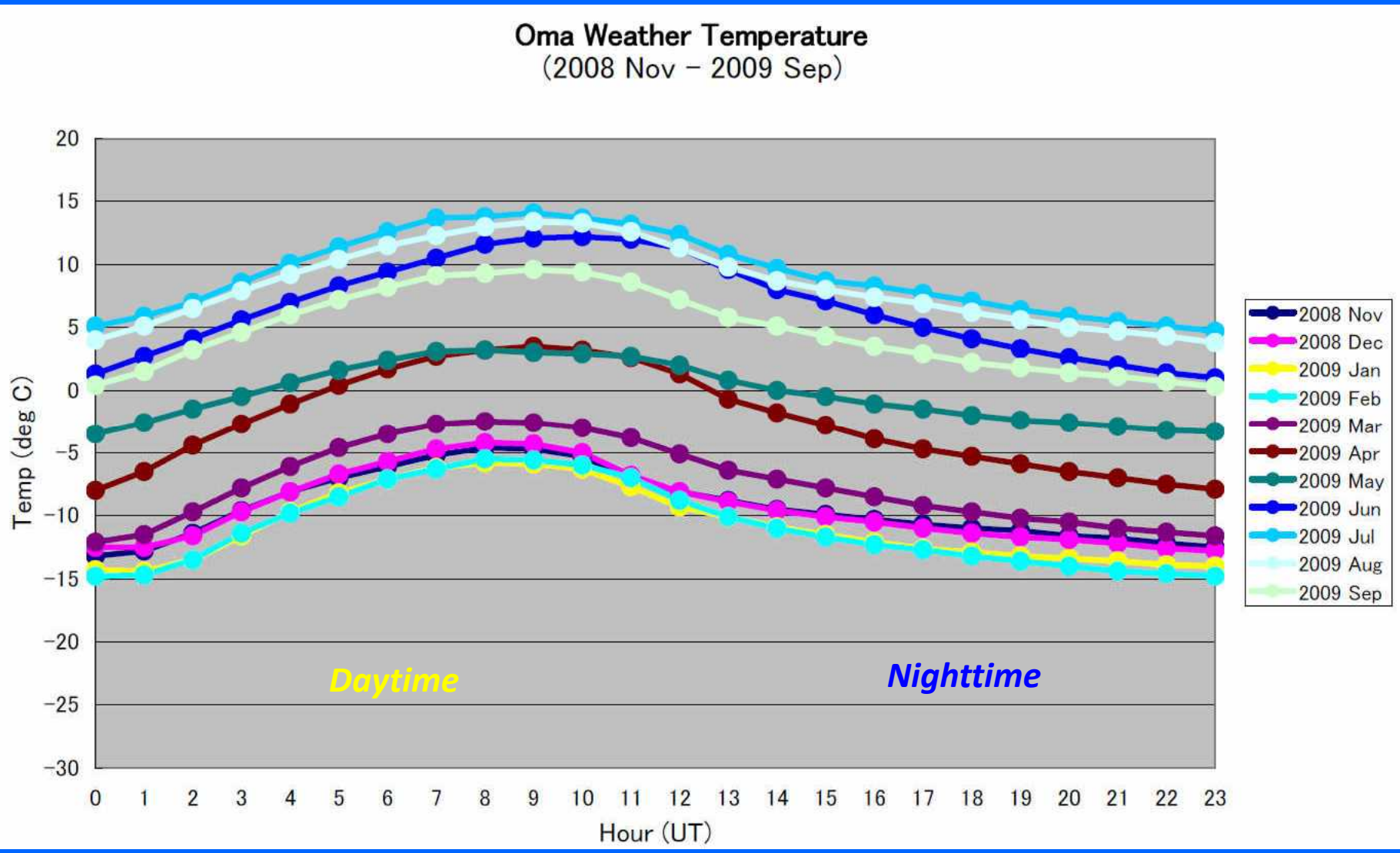
Comparison of image deterioration at Z_h with seeing by SBIG camera at Oma



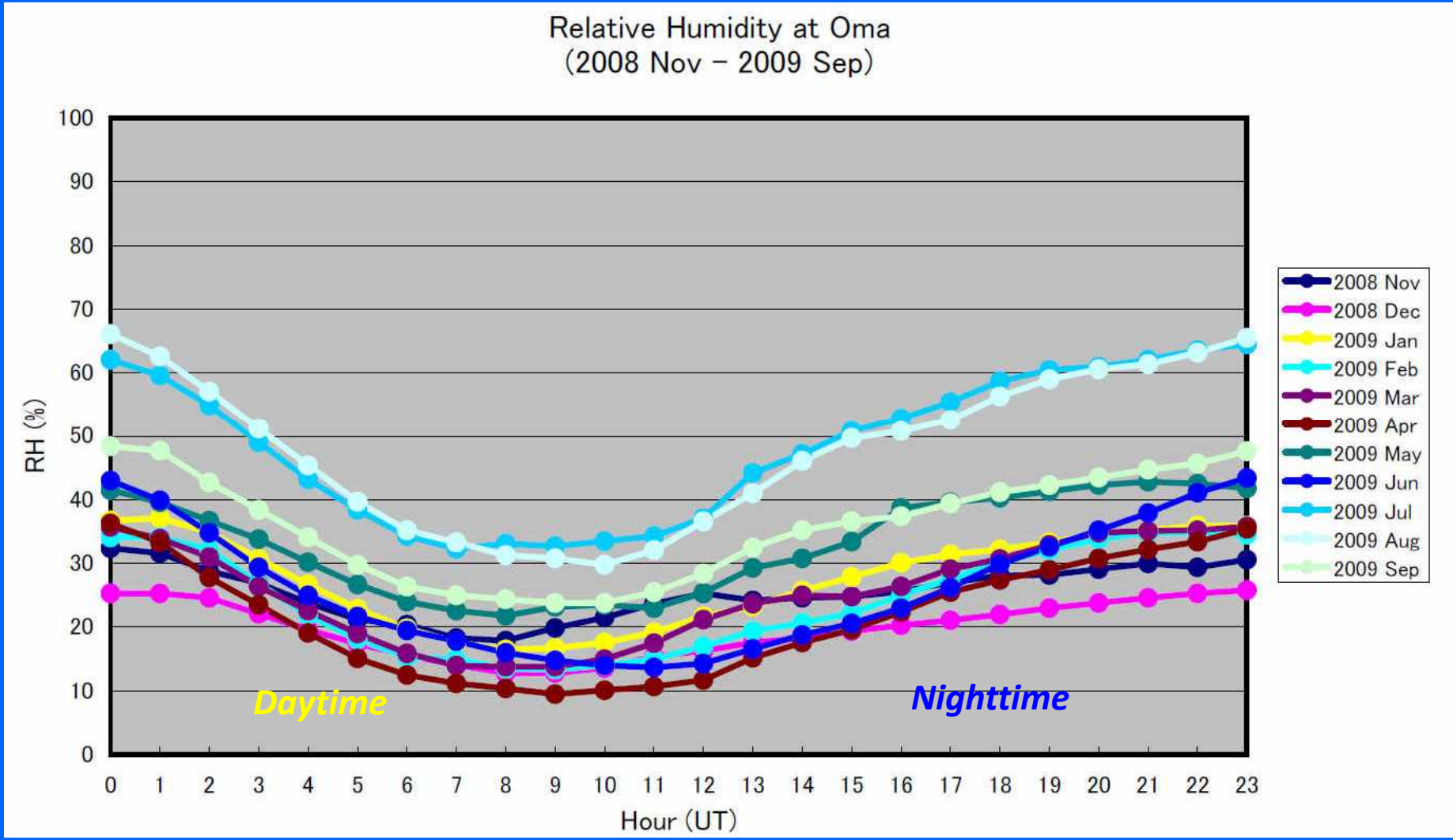
Comparison of image deterioration at Z_h with seeing w/ SBIG camera at Oma



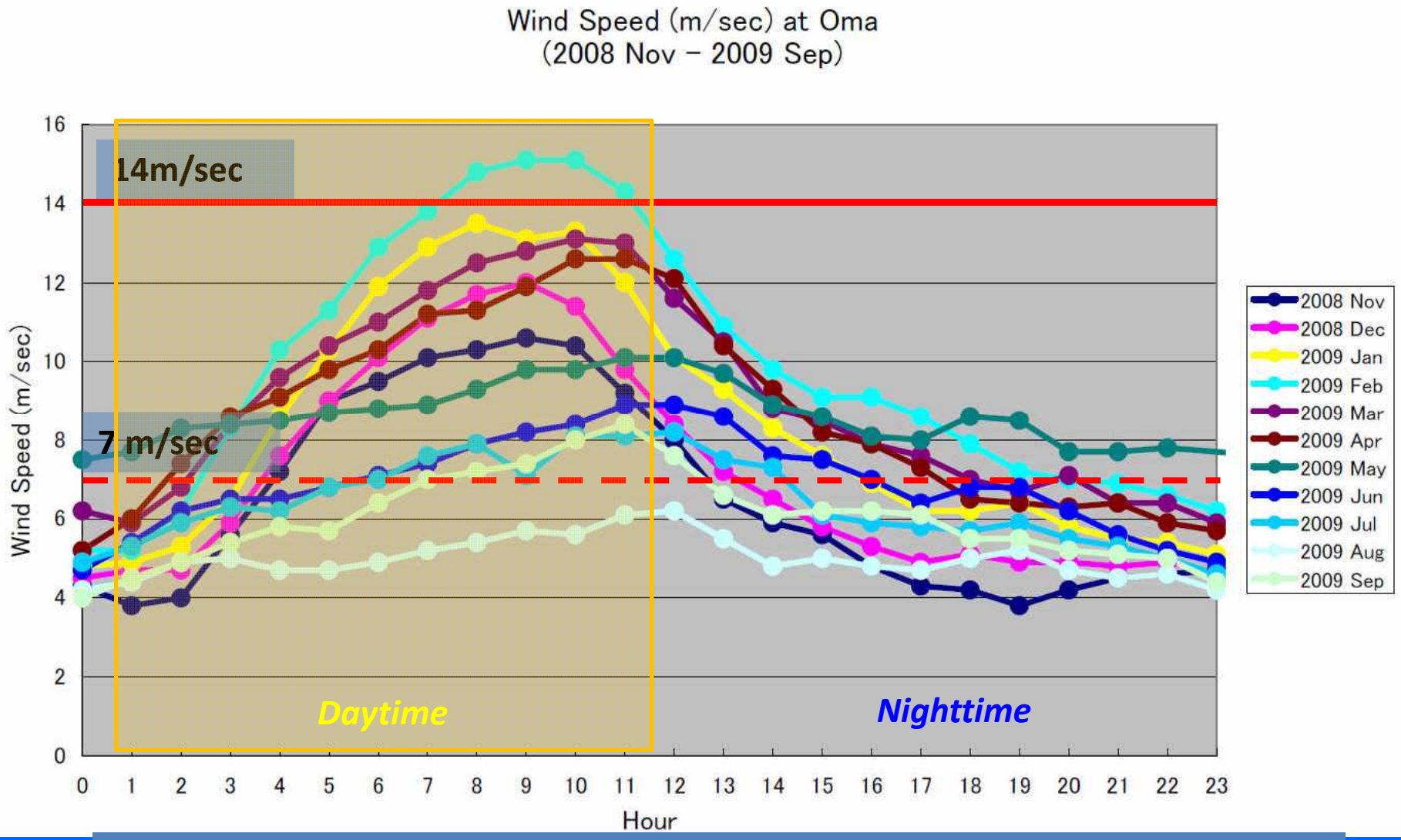
Weather data at Oma in 2008 and 2009



Weather data at Oma in 2008 and 2009

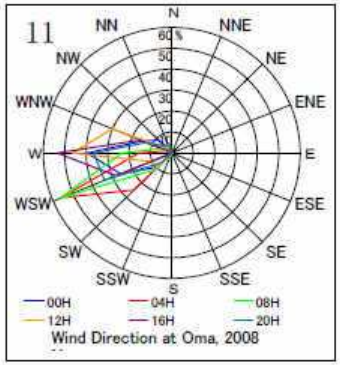


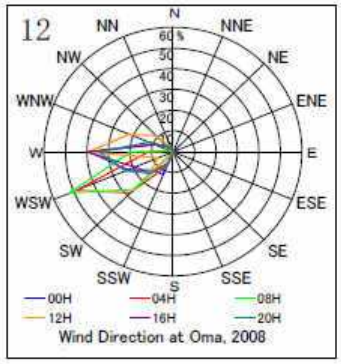
Weather data at Oma in 2008 and 2009

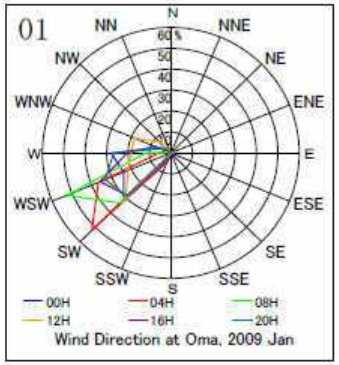


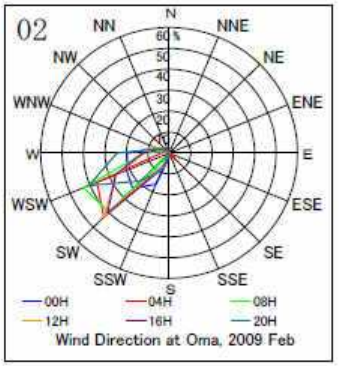
Wind Speed in winter is typically strong at Oma, which affects local seeing. For Subaru telescope, operation is limited under Wind Speed of 14 m/sec and its perfromance is guranteed under 7m/sec.

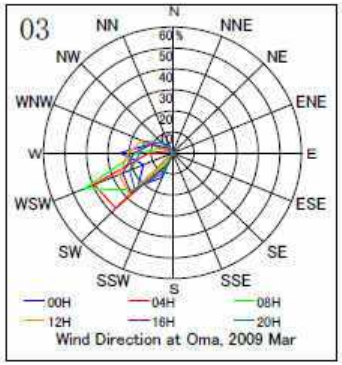
Weather Direction at Oma in 2008 and 2009

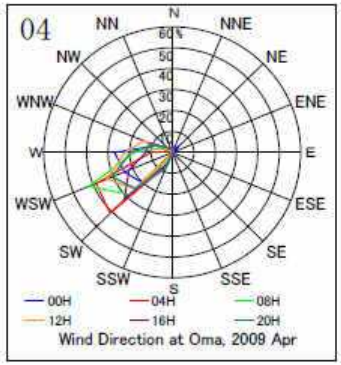


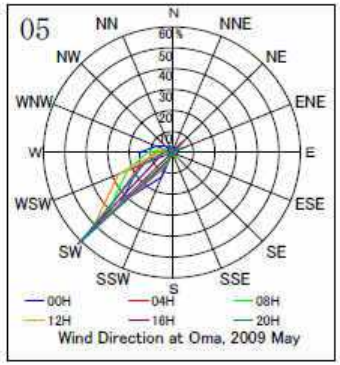


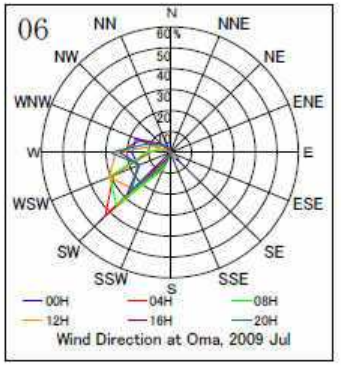


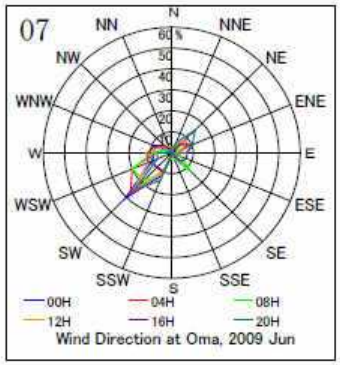


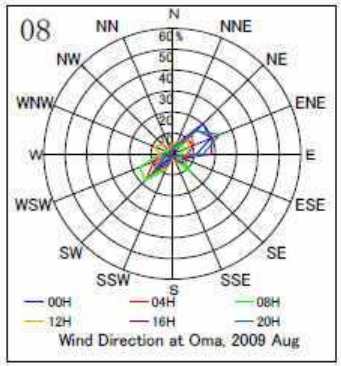


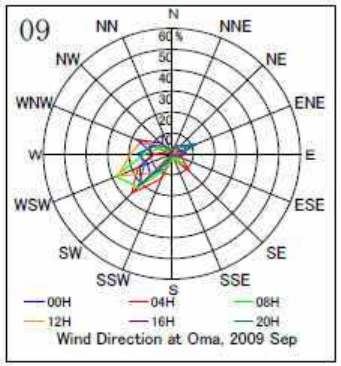












Oma Wind Direction
2008 Nov – 2009 Sep

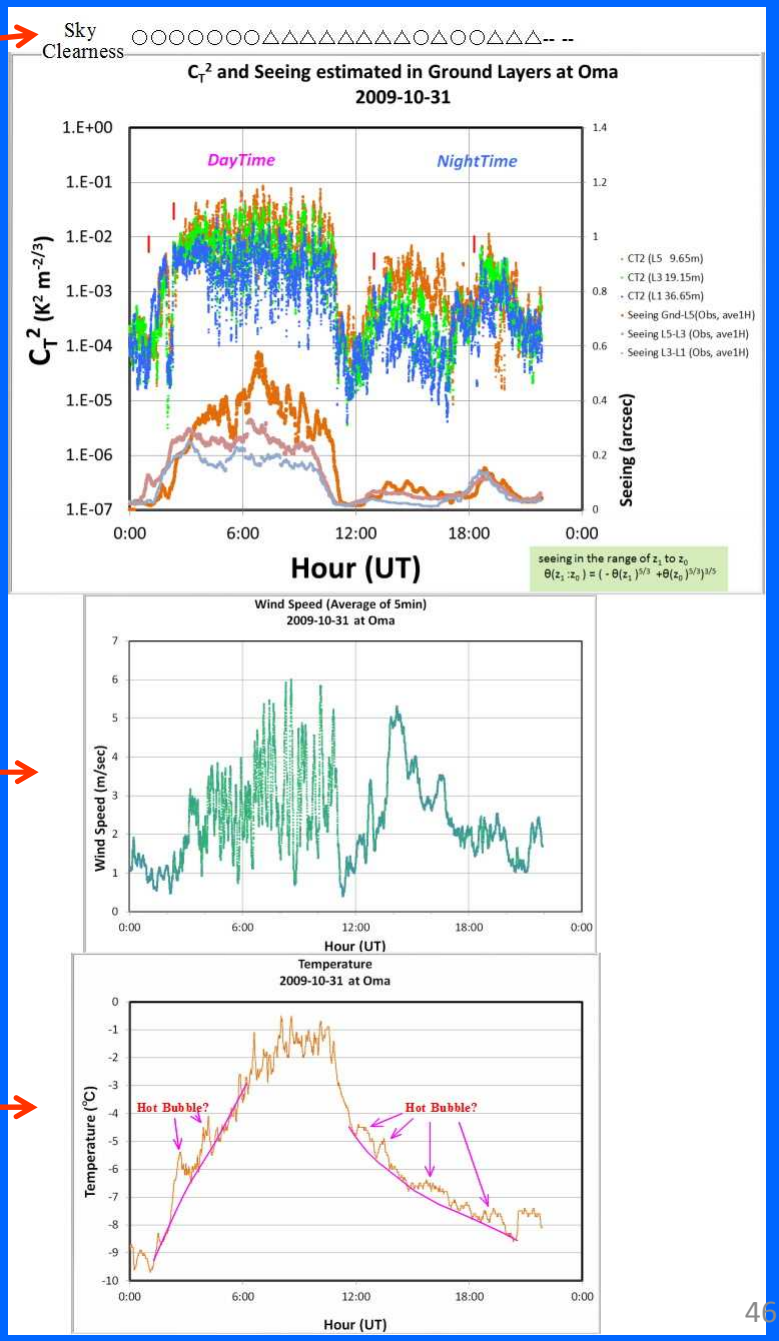
Sky is clear or fine?

Relation among C_T^2 distribution and Wind Speed

(2009-10-31 at Oma)

Wind Speed

Temperature



Z:¥00SiteSurveyData¥000_aSiteSurveySummary¥
Oma_20091031_CT2_Seeing_WindSpeed_Temp.jpg

Sky is clear or fine?

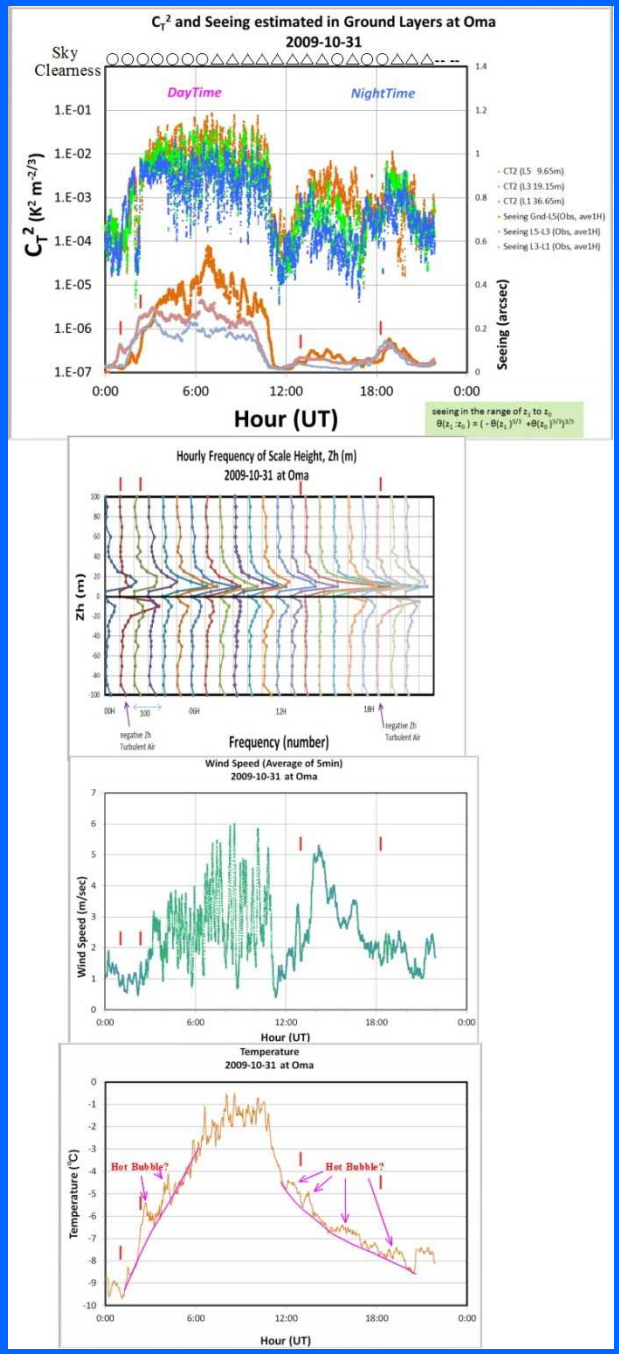
Relation among C_T^2 distribution and Wind Speed

(2009-10-31 at Oma)

Zh histogram

Wind Speed

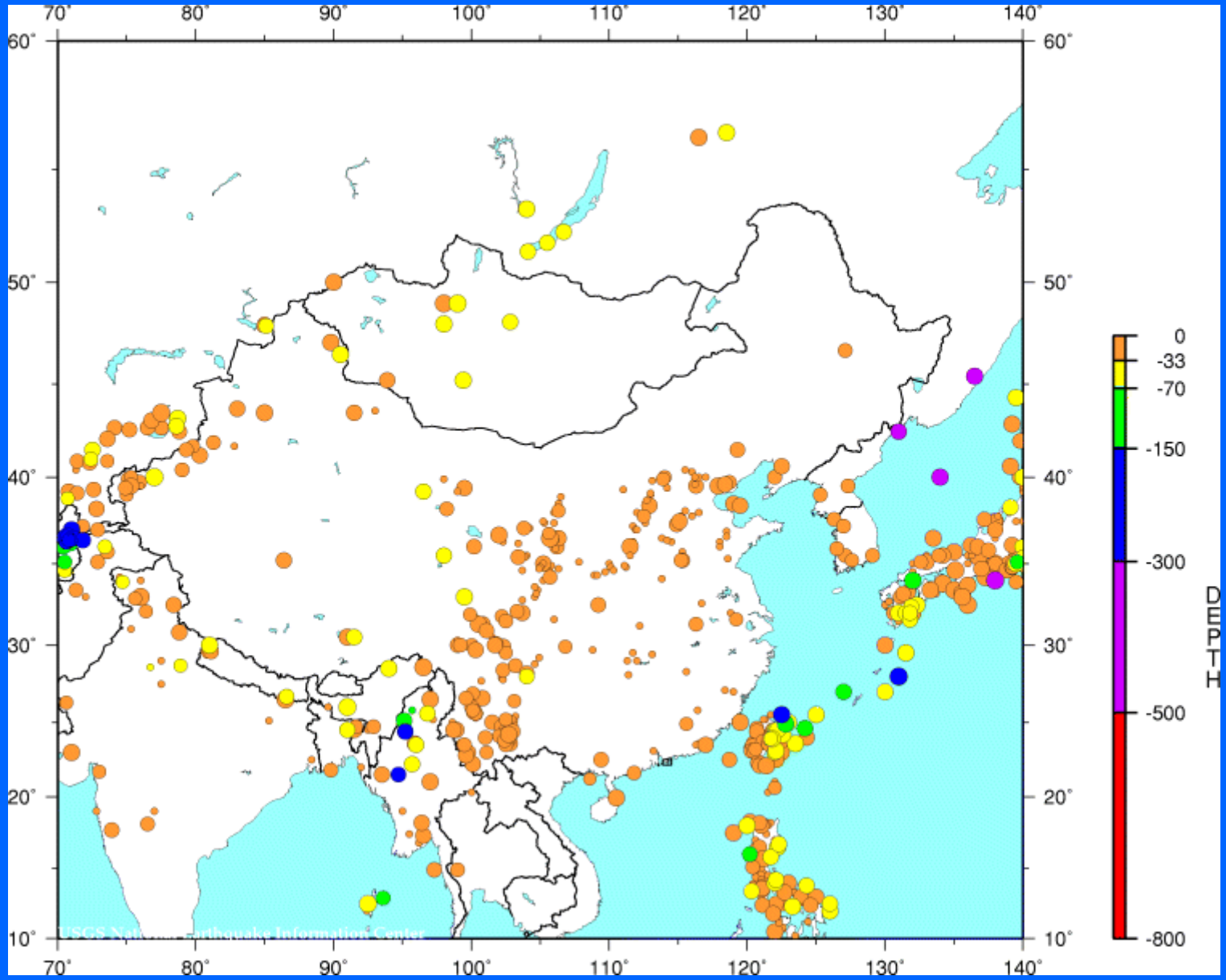
Temperature



Z:¥00SiteSurveyData¥000_aSiteSurveySummary¥
Oma_20091031_CT2_Seeing_WindSpeed_Temp.jpg

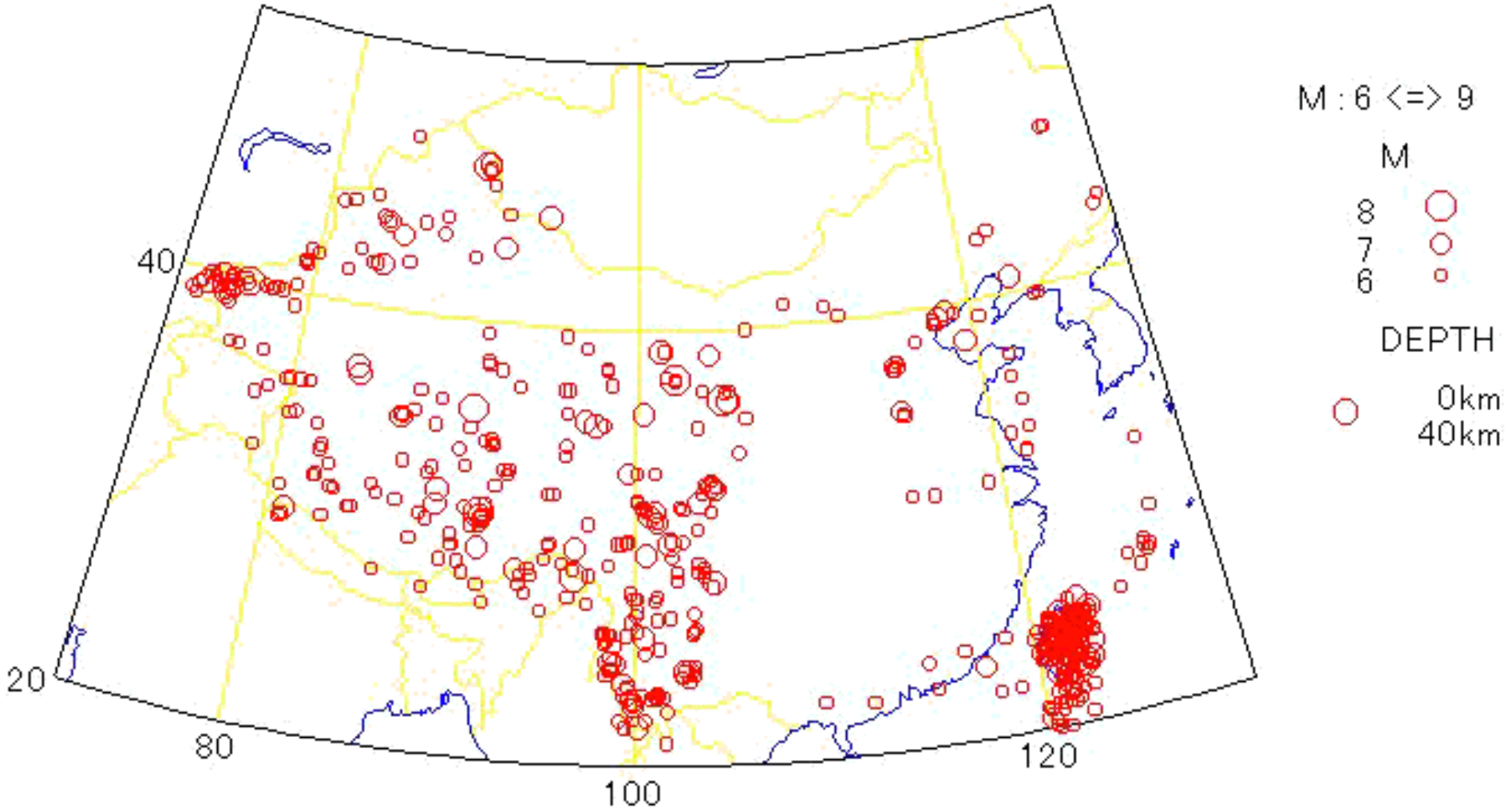
Earthquake in China

SeismicBigMagCentralAsia_USGS.gif



Seismic activity in Tibet

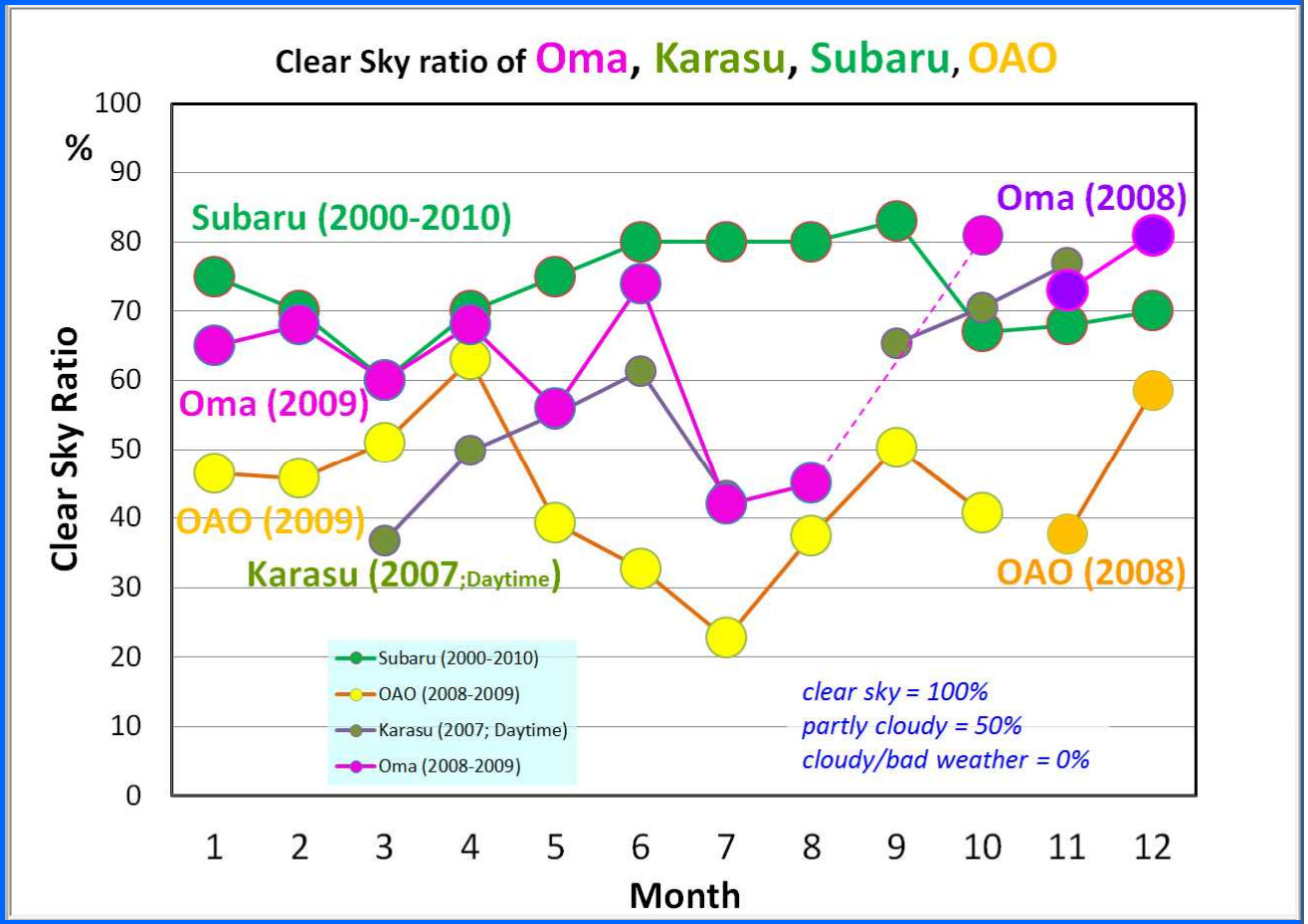
Data from GAME-Tibet project



MIR CloudMonitor

Clear sky ratios at Oma, except summer monsoon season, are around 70%, which are comparable to at Mauna Kea, Hawaii, and much bettre than at Okayama, Japan.

Subaru : statistics during 2000-2010
OAO: summary report during 2008-2009



C_T^2 measurements

Location	Scale Height Zh (meter)	Image Deterio. at Zh (arcsec)
Karasu	12 m	0.14
Oma	16 m	0.08
OAO (Japan)	13 m	0.03

should evaluate bad effect of *Strong wind* at the sites

On-going Collaborative Site Testing at Ali

Item	Instrument		Status
Weather condition	Vaisala:WXT510		Working at Ali
Sky condition	MIR Cloud Mon Visible all-sky camera		Working at Ali Working at Ali
Dust	Dust Counter TSI:DustTrak8520		
DIMM	(NAOC)		
SCIDAR	(NAOC)		
Surface Layer Turbulence	CT2 sensors on tower		Constructed soon this year
Turbulence in upper layer	SNODAR		Planning (*tomorrow talk*)
Housing	w/ electric power		Available at Ali
	O_2 supply		Comfortable at 5100m !
Road			need 4WD
Internet	LAN		Planned (not yet available stably)

apply site testing instruments with analysis tools to evaluate observational conditions at Ali for years.


The End
謝謝、ありがとう、Thank you！