Cloud Birth and Fraction

Dave Turner

Wei Zhao

Elizabeth Smith

Allison McComiskey

Jingyi Chen

George Duffy

*What is a cloud?

What is a cloud?

- A visible aggregate of minute water droplets and/or ice particles in the atmosphere above the Earth's surface.

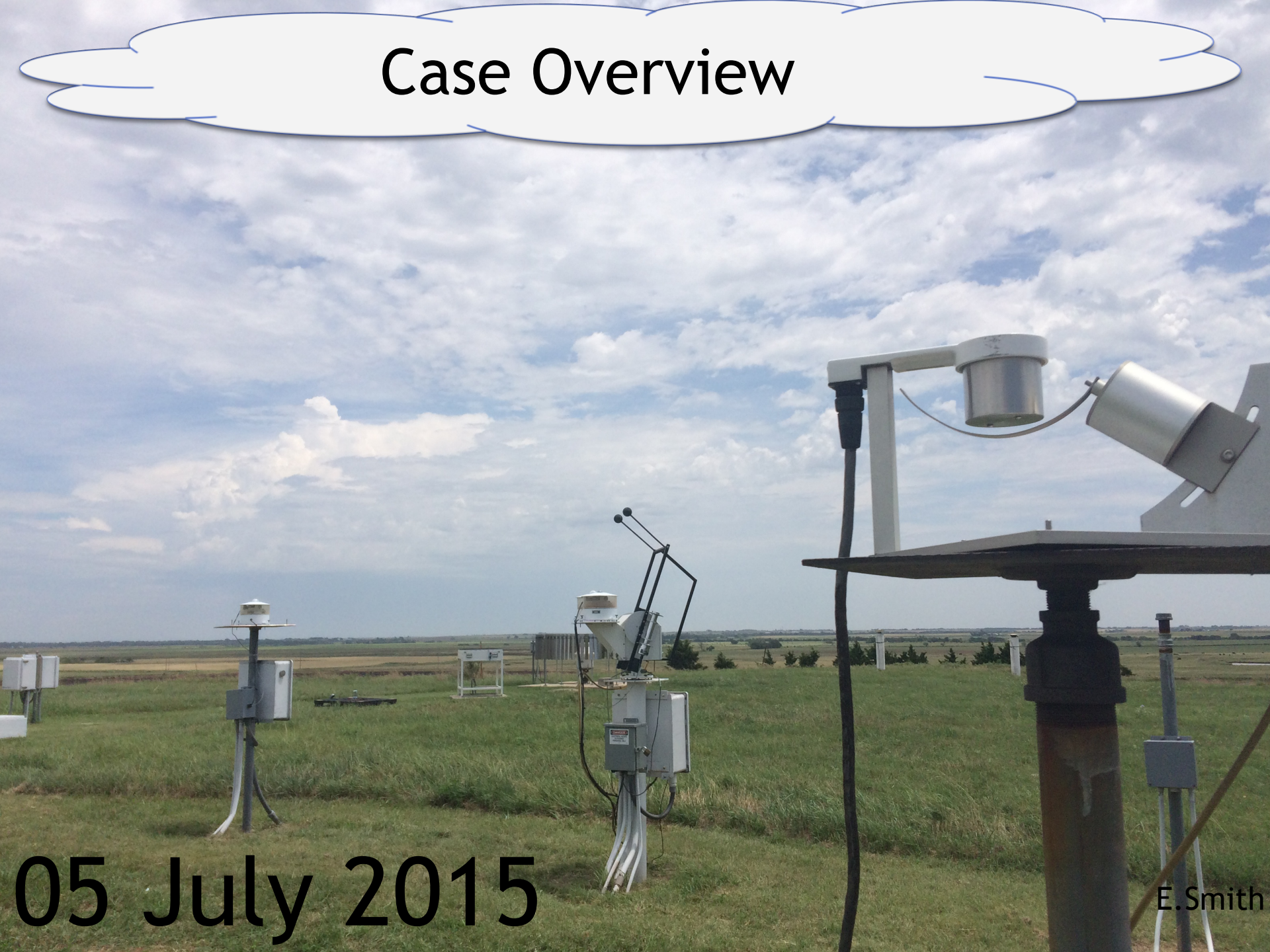
-AMS glossary

What is a cloud?

- A visible aggregate of minute water droplets and/or ice particles in the atmosphere above the Earth's surface.

-AMS glossary

Case Overview

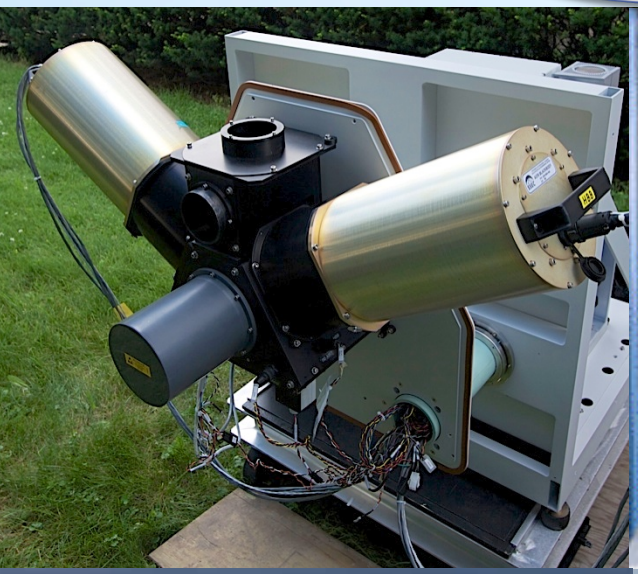


05 July 2015

E.Smith

Instruments

Instrument photo source: ARM.gov



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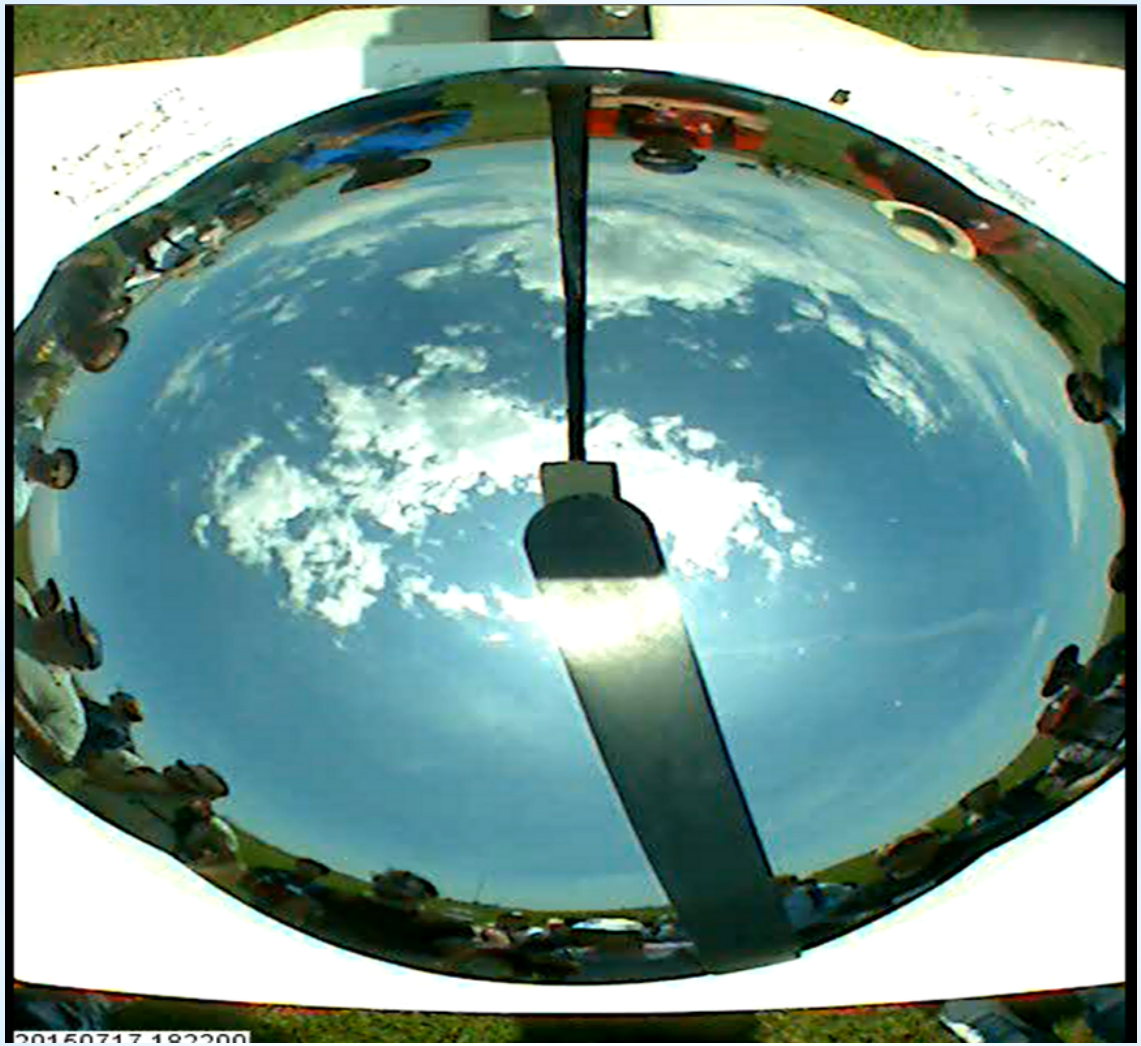
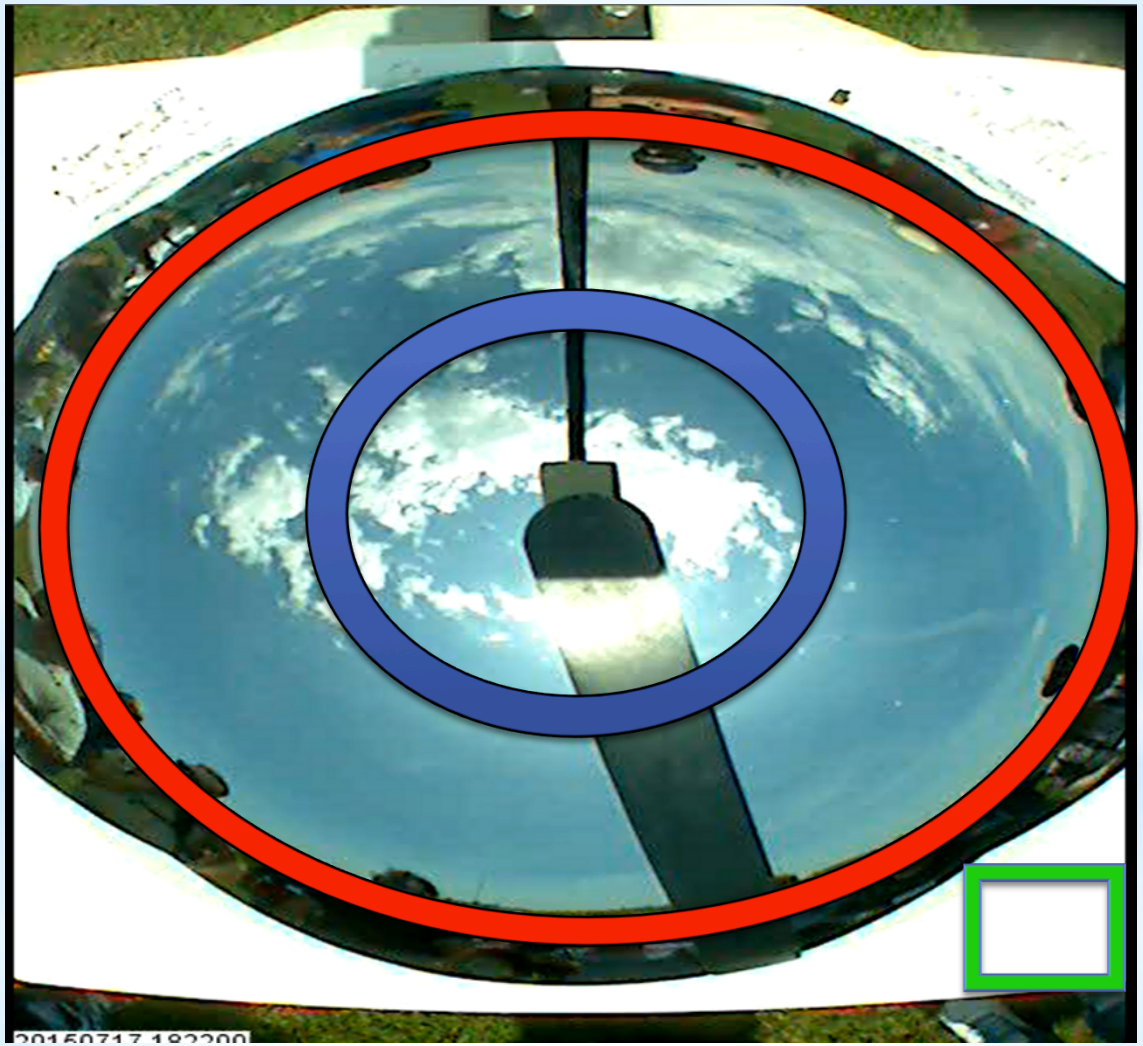
Instruments

*Analysis:

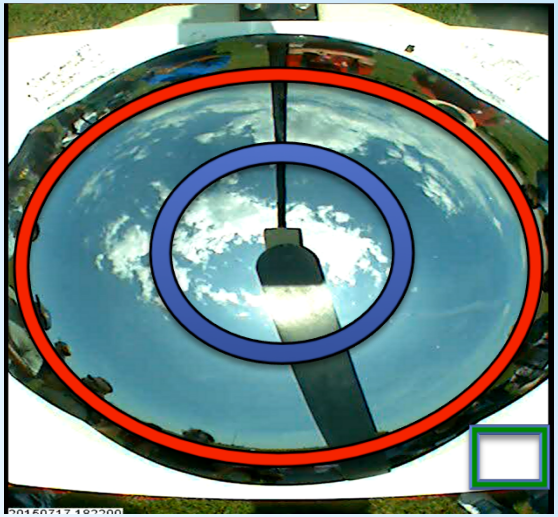
Total Sky Imager



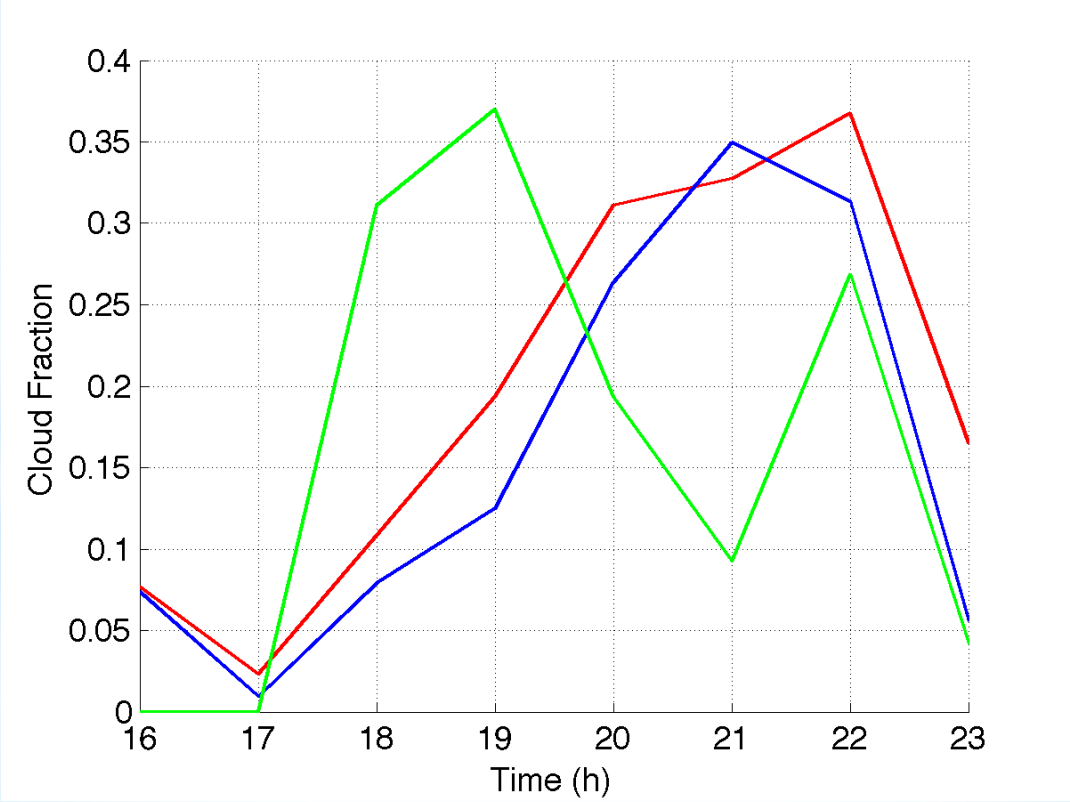
Total Sky Imager

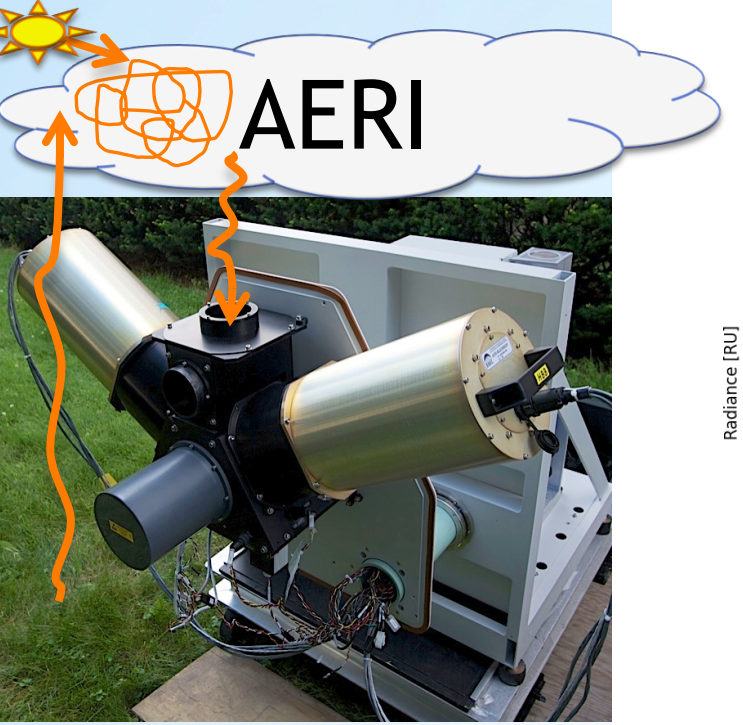


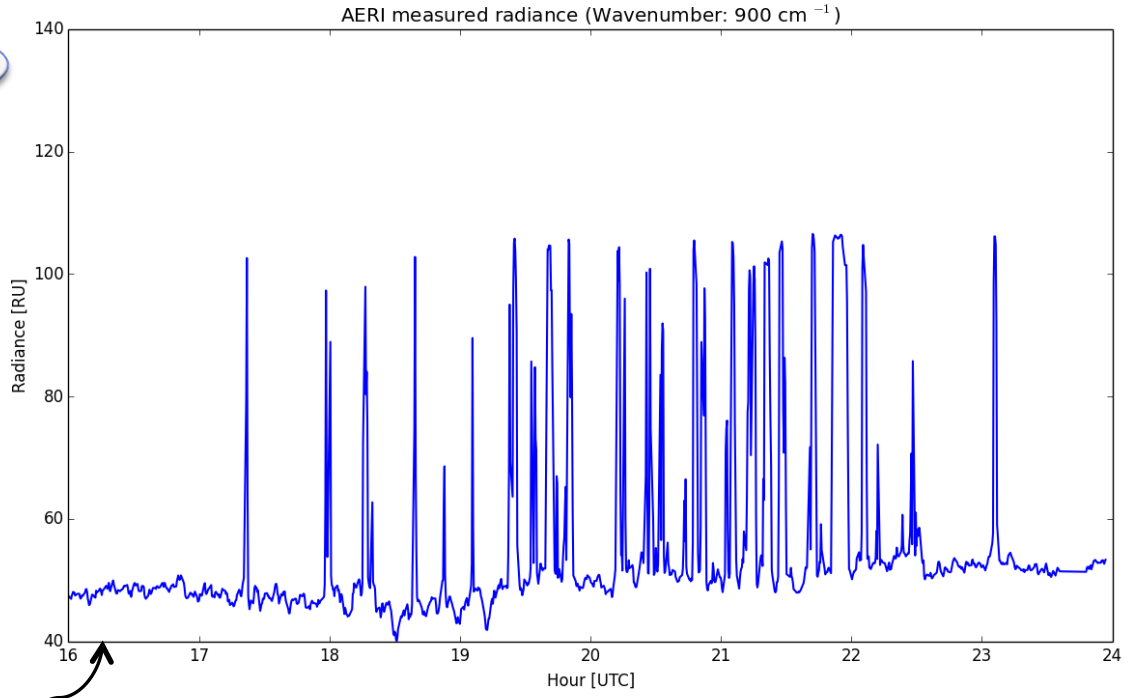
Total Sky Imager

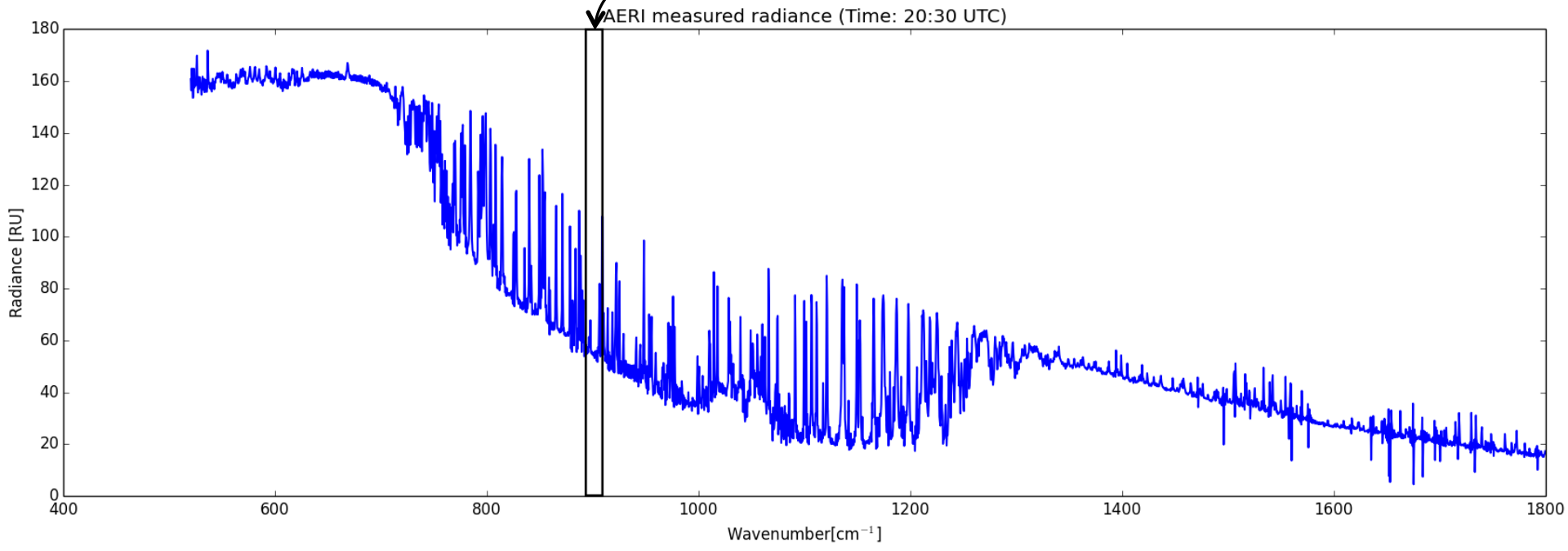


Whole sky
Zenith
Overhead



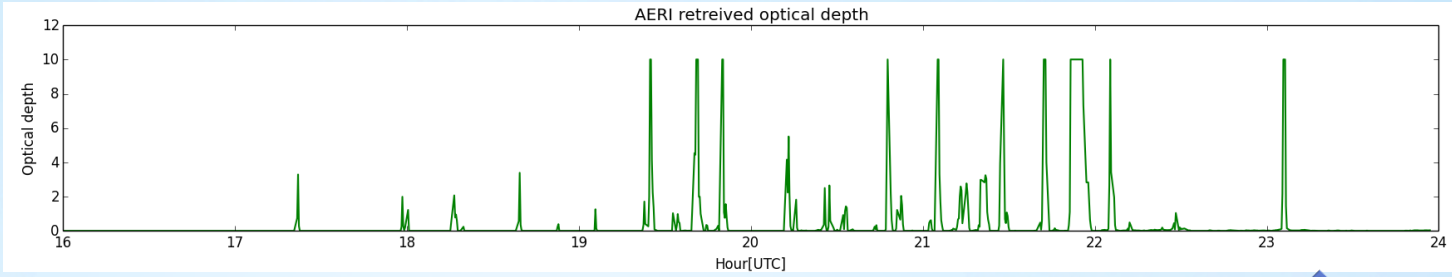

AERI

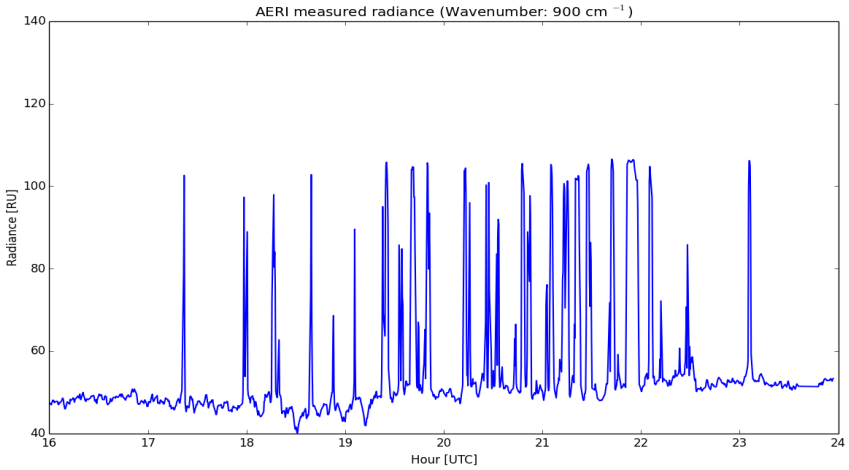

AERI measured radiance (Wavenumber: 900 cm $^{-1}$)
Radiance [RU]
Hour [UTC]
140
120
100
80
60
40
16
17
18
19
20
21
22
23
24


AERI measured radiance (Time: 20:30 UTC)
Radiance [RU]
Wavenumber[cm^{-1}]
180
160
140
120
100
80
60
40
20
0
400
600
800
1000
1200
1400
1600
1800

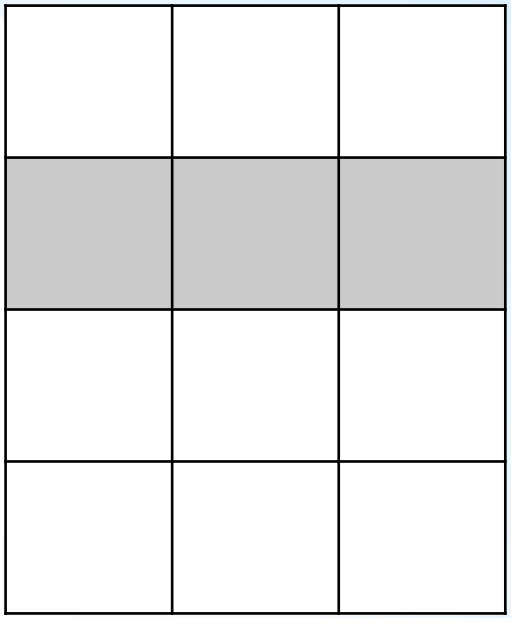
AERI

How do we get from radiance to optical depth?

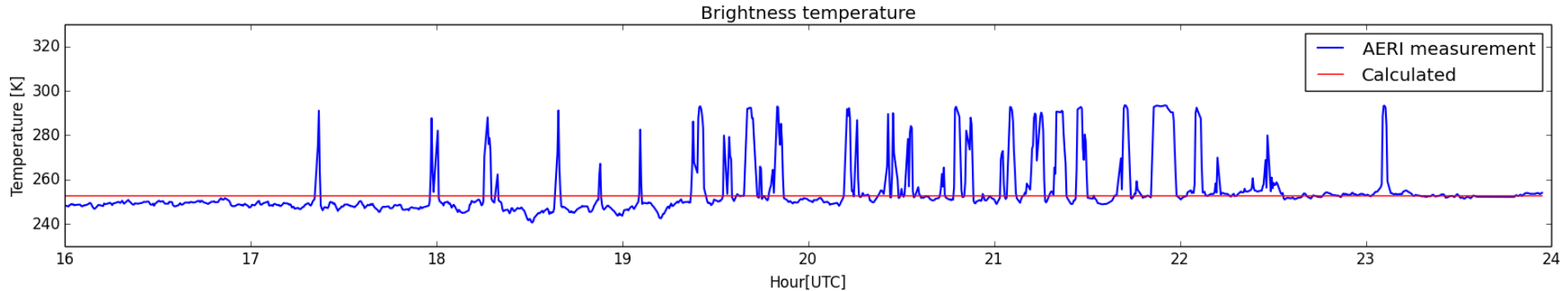




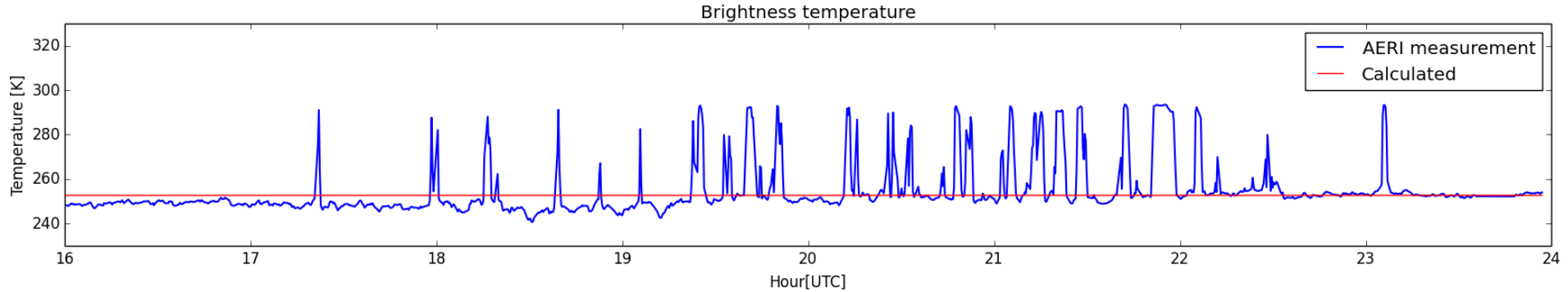
$$B(T) = \frac{2hc^2\nu^3}{\exp\left(\frac{hc\nu}{kT}\right) - 1}$$

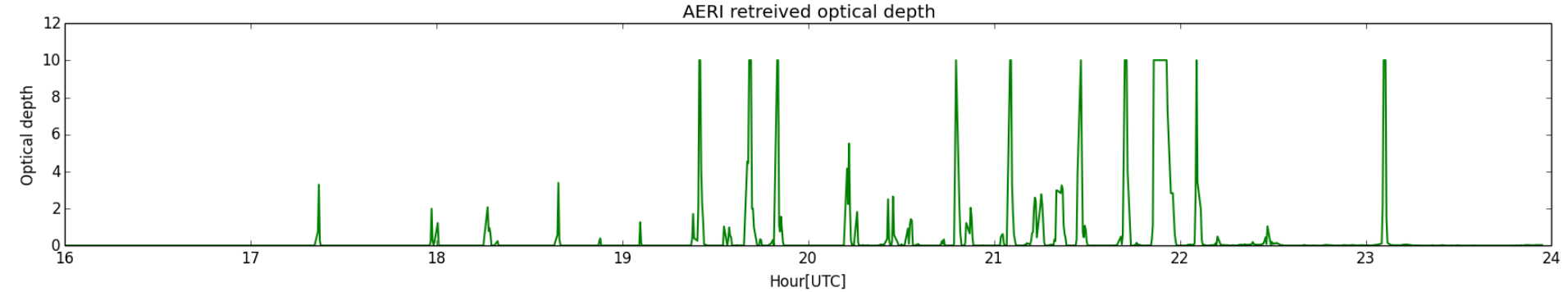


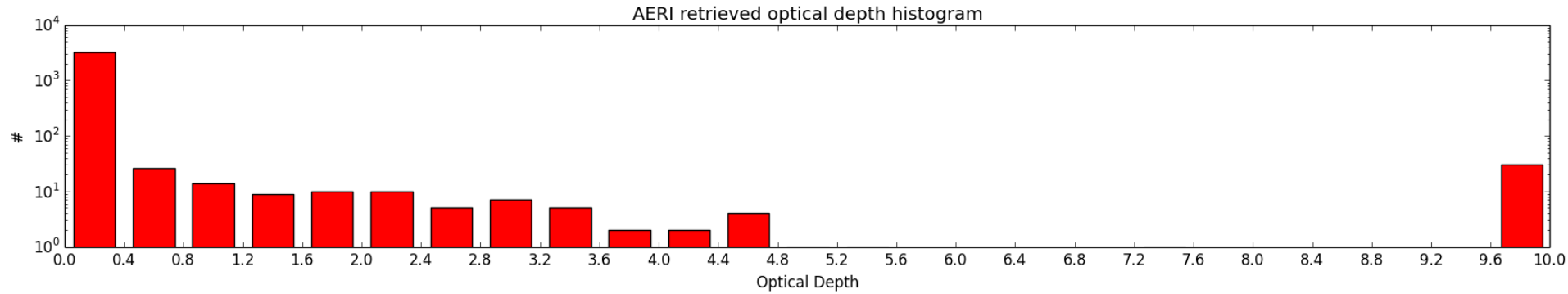
Increase the cloud optical depth until the measured brightness temperature is calculated



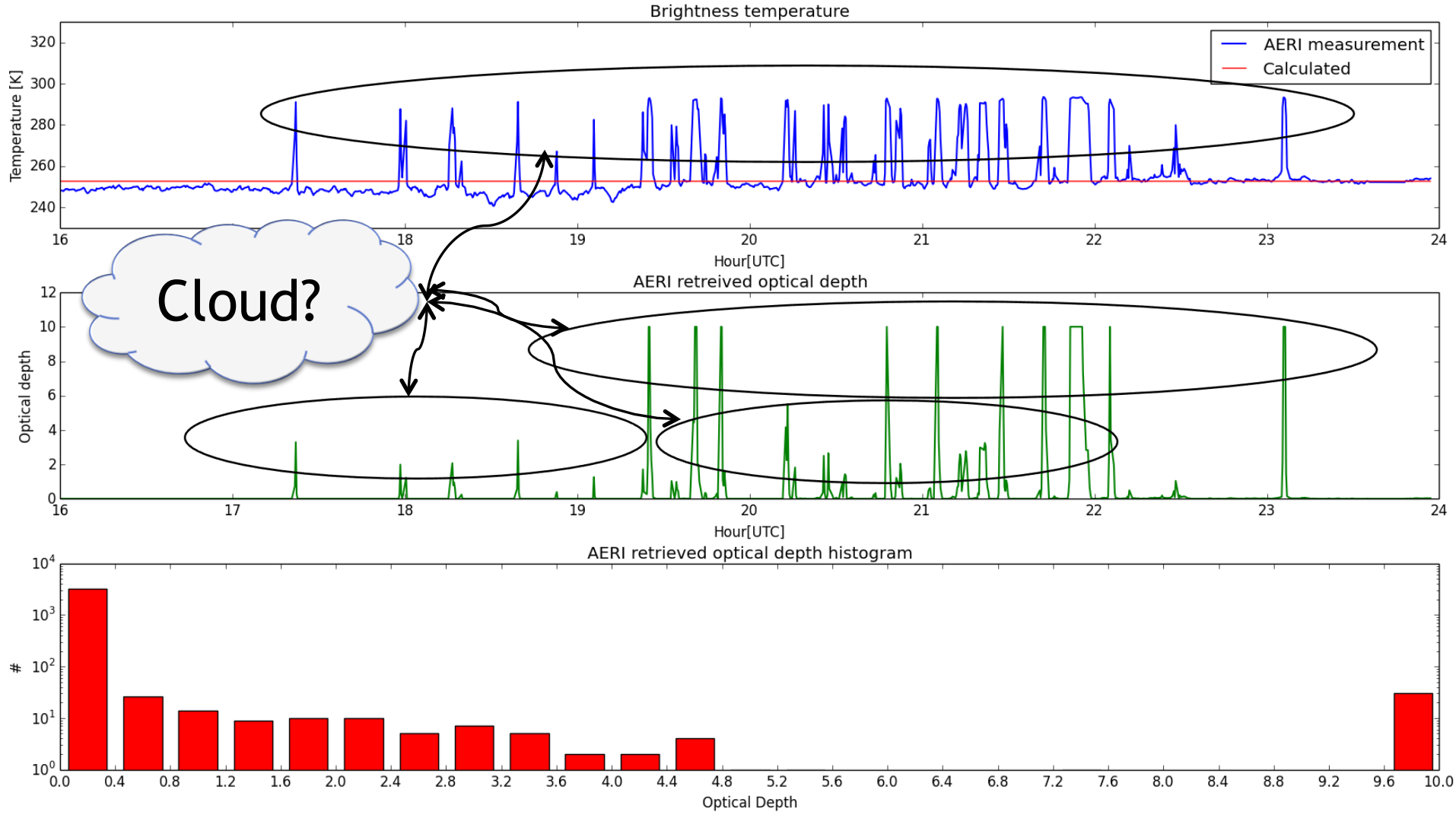
AERI


Brightness temperature
AERI measurement
Calculated
Temperature [K]
320
300
280
260
240
16
17
18
19
20
21
22
23
24
Hour[UTC]

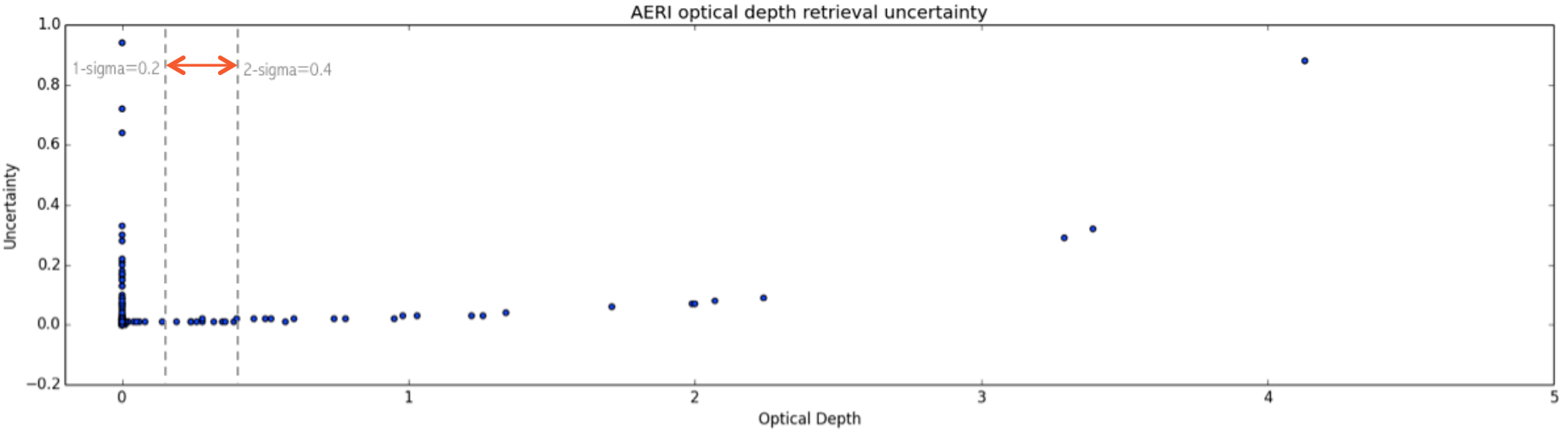

AERI retreived optical depth
Optical depth
12
10
8
6
4
2
0
16
17
18
19
20
21
22
23
24
Hour[UTC]


AERI retrieved optical depth histogram
#
10^4
10^3
10^2
10^1
10^0
0.0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
3.6
4.0
4.4
4.8
5.2
5.6
6.0
6.4
6.8
7.2
7.6
8.0
8.4
8.8
9.2
9.6
10.0
Optical Depth

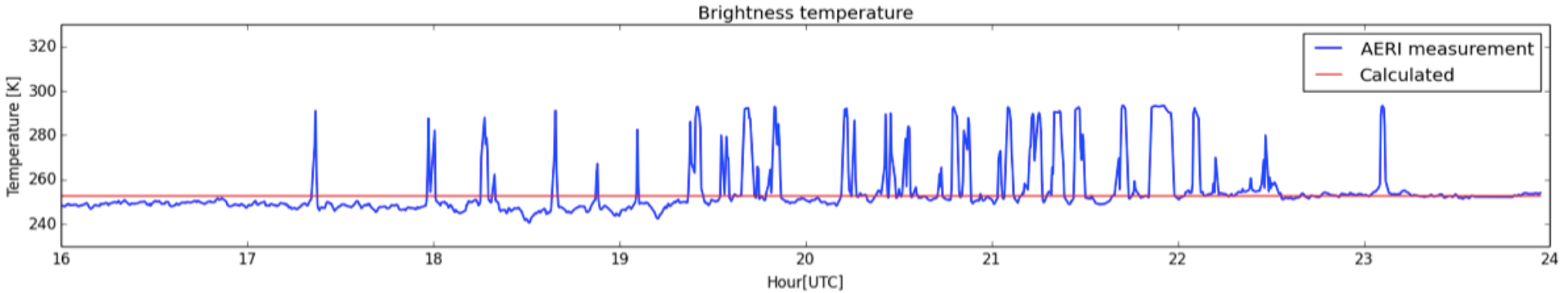
AERI

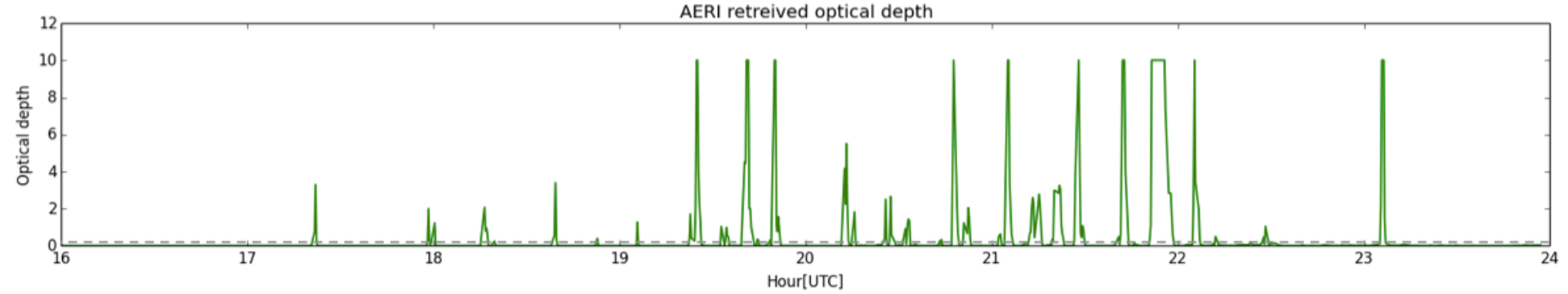

Brightness temperature
AERI measurement
Calculated
Temperature [K]
320
300
280
260
240
16
18
19
20
21
22
23
24
Hour[UTC]
Cloud?
AERI retreived optical depth
Optical depth
12
10
8
6
4
2
0
16
17
18
19
20
21
22
23
24
Hour[UTC]
AERI retrieved optical depth histogram
#
10^4
10^3
10^2
10^1
10^0
0.0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
3.6
4.0
4.4
4.8
5.2
5.6
6.0
6.4
6.8
7.2
7.6
8.0
8.4
8.8
9.2
9.6
10.0
Optical Depth

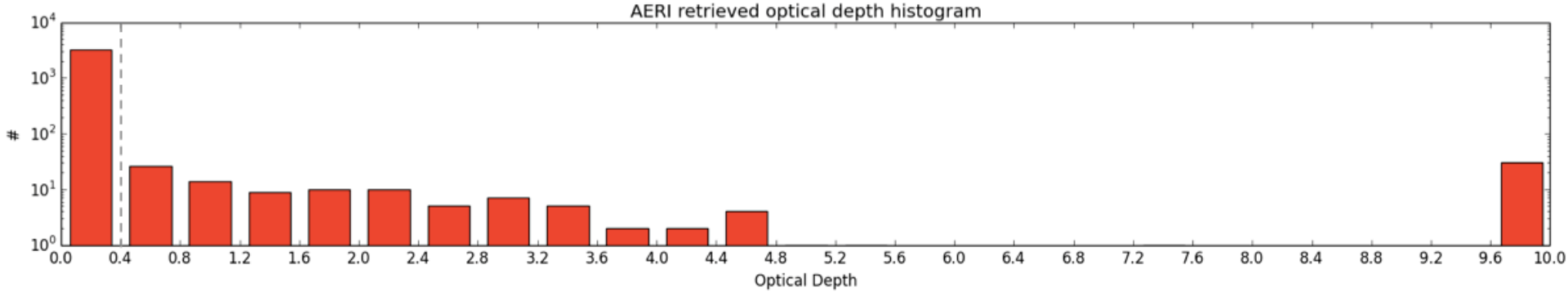
AERI


AERI optical depth retrieval uncertainty
1-sigma=0.2
2-sigma=0.4
Uncertainty
Optical Depth
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
0
1
2
3
4
5

AERI


Brightness temperature
AERI measurement
Calculated
Temperature [K]
320
300
280
260
240
16
17
18
19
20
21
22
23
24
Hour[UTC]


AERI retreived optical depth
Optical depth
12
10
8
6
4
2
0
16
17
18
19
20
21
22
23
24
Hour[UTC]


AERI retrieved optical depth histogram
#
10^4
10^3
10^2
10^1
10^0
0.0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
3.6
4.0
4.4
4.8
5.2
5.6
6.0
6.4
6.8
7.2
7.6
8.0
8.4
8.8
9.2
9.6
10.0
Optical Depth

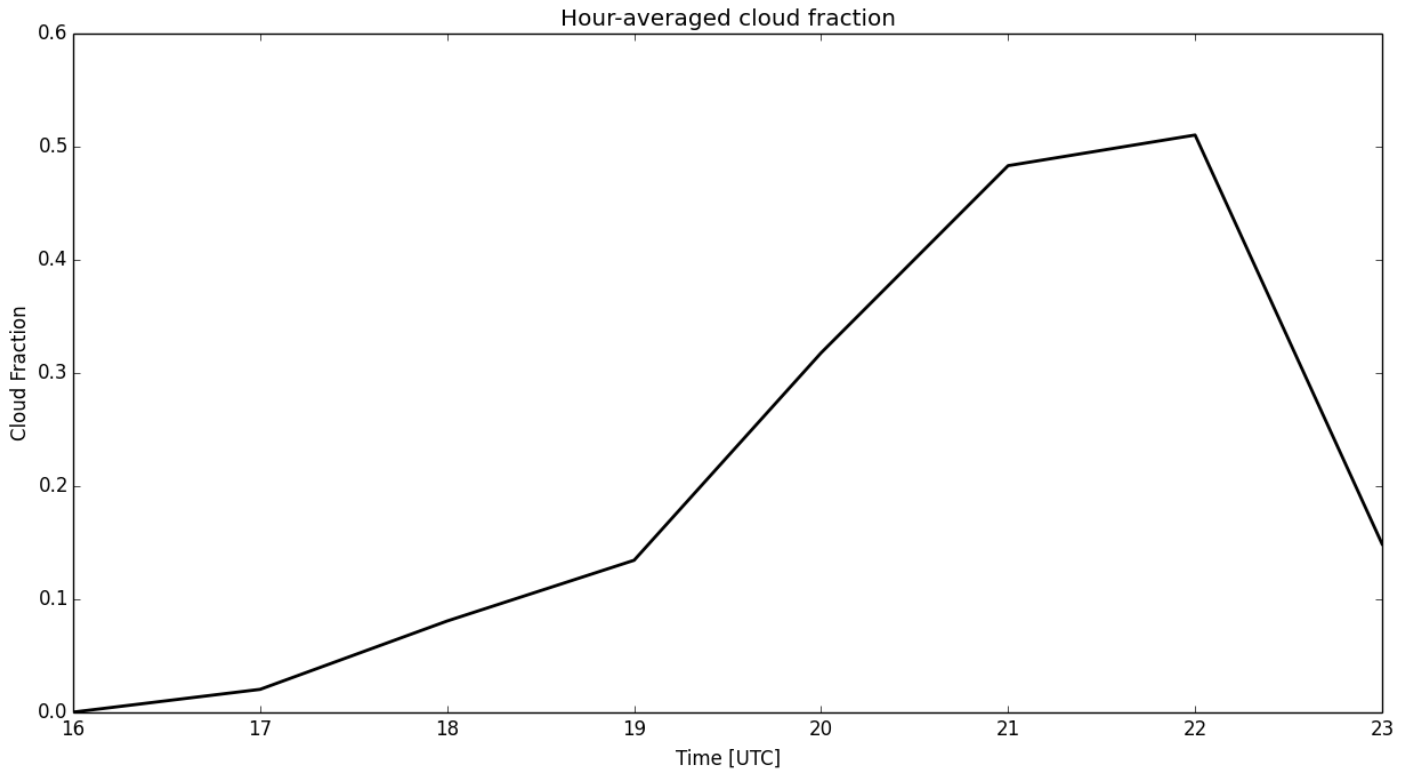
AERI

Is there a cloud?

```
for i in range(time):
    if tau[i]>.39: # Threshold for cloud ID
        cloud_id.append(1.)
        #there is a cloud, value = 1
    else:
        cloud_id.append(0.)
        #there is no cloud, value = 0
```

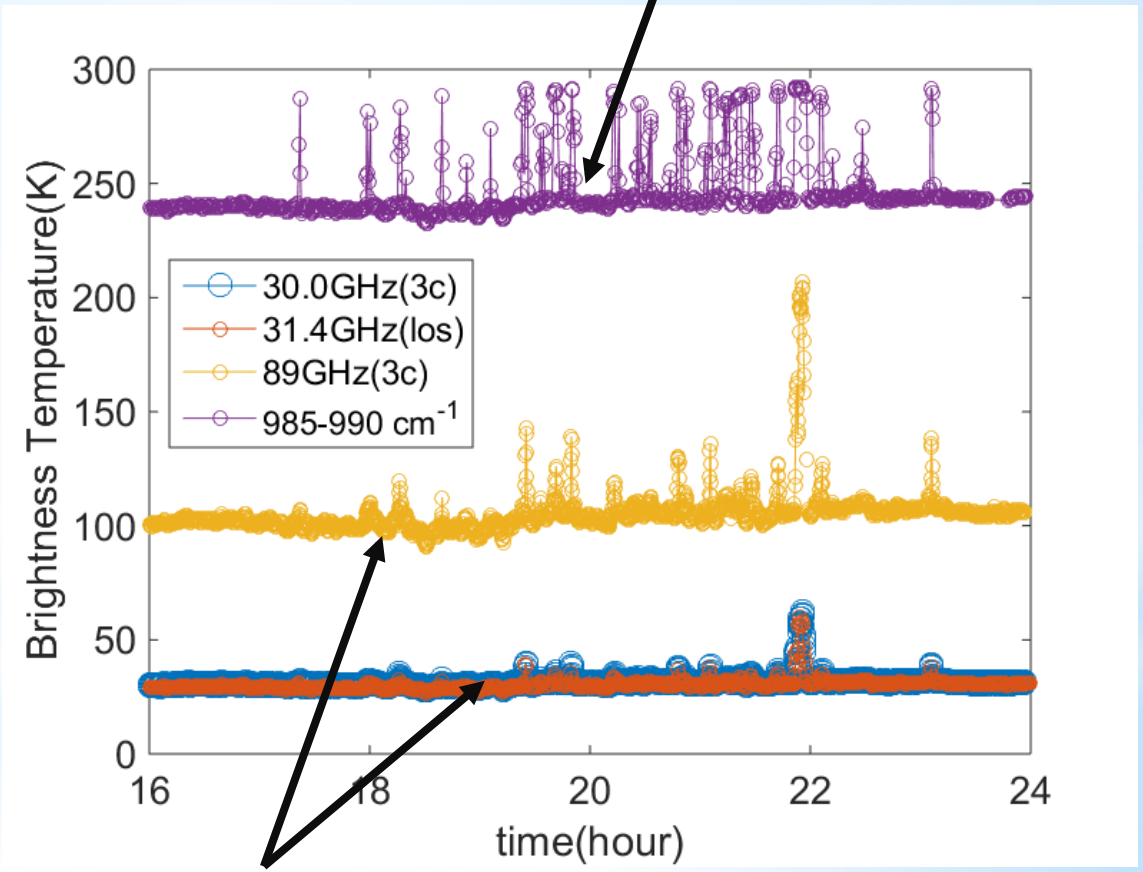
What is the cloud fraction?

```
for i in range(hourly):
    cloud_f[i]=np.mean(cloud_id[i:i+1])
    print cloud_f[i]
```



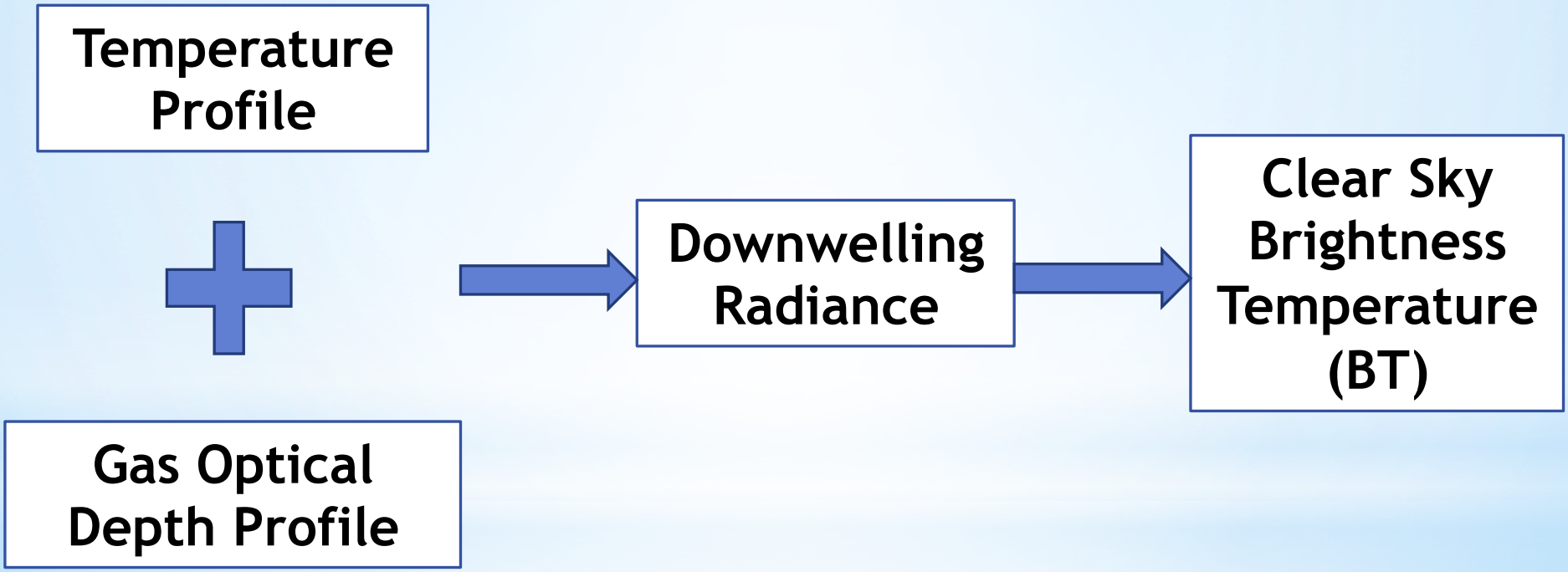
Microwave Radiometer

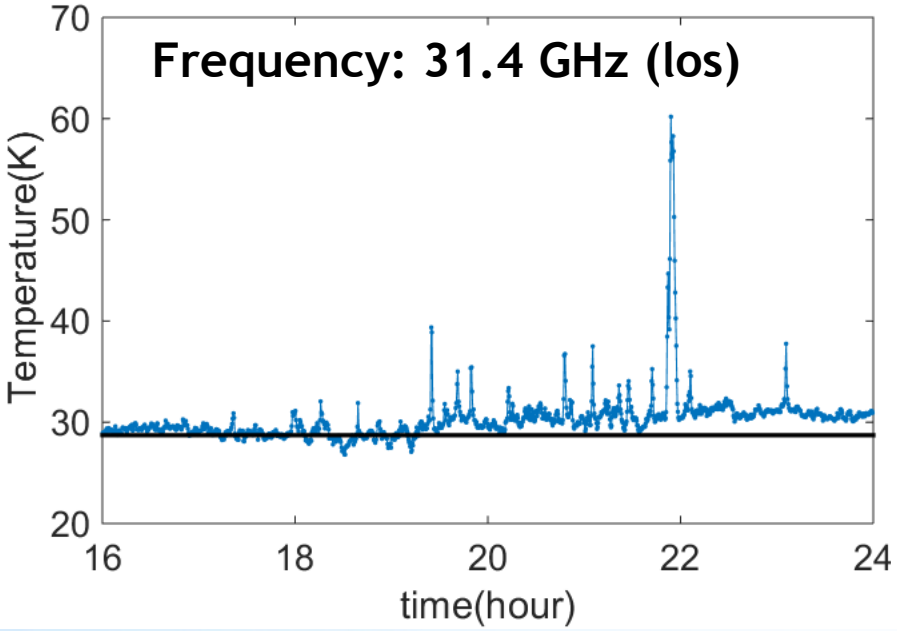
AERI

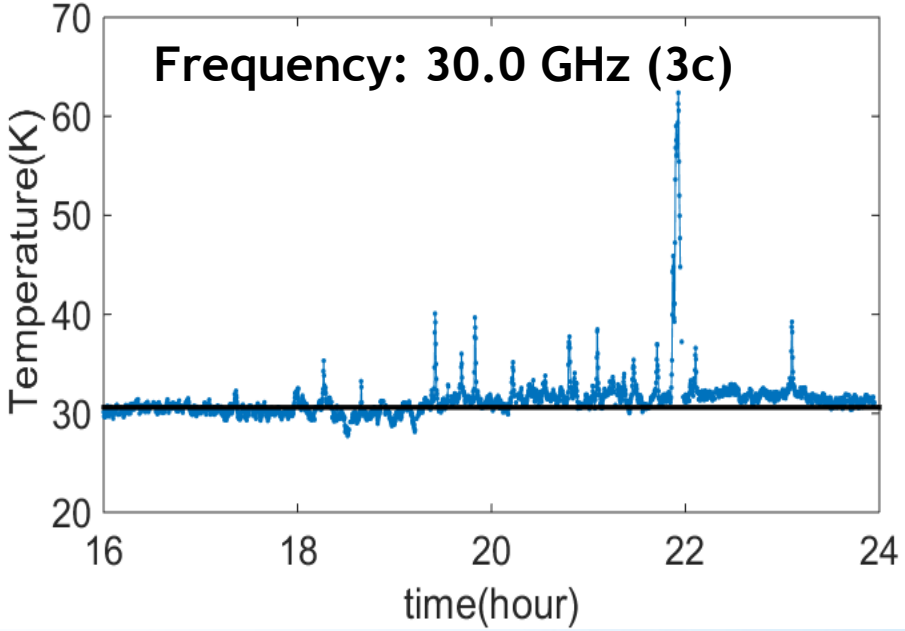


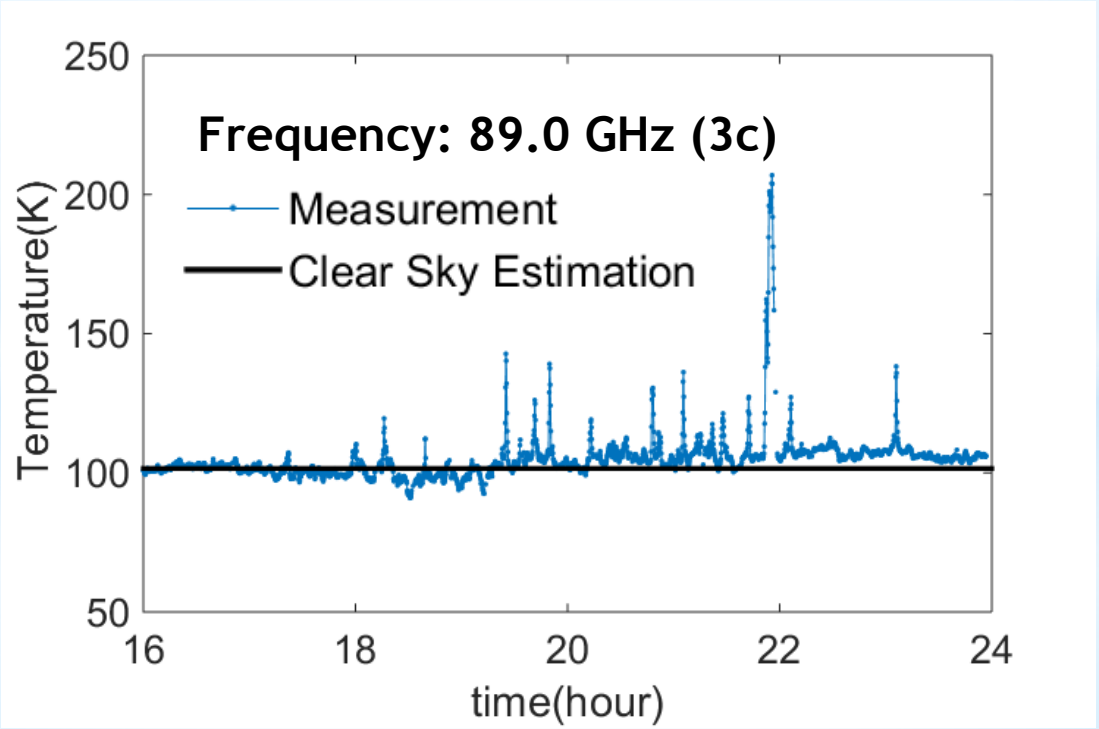
MWR

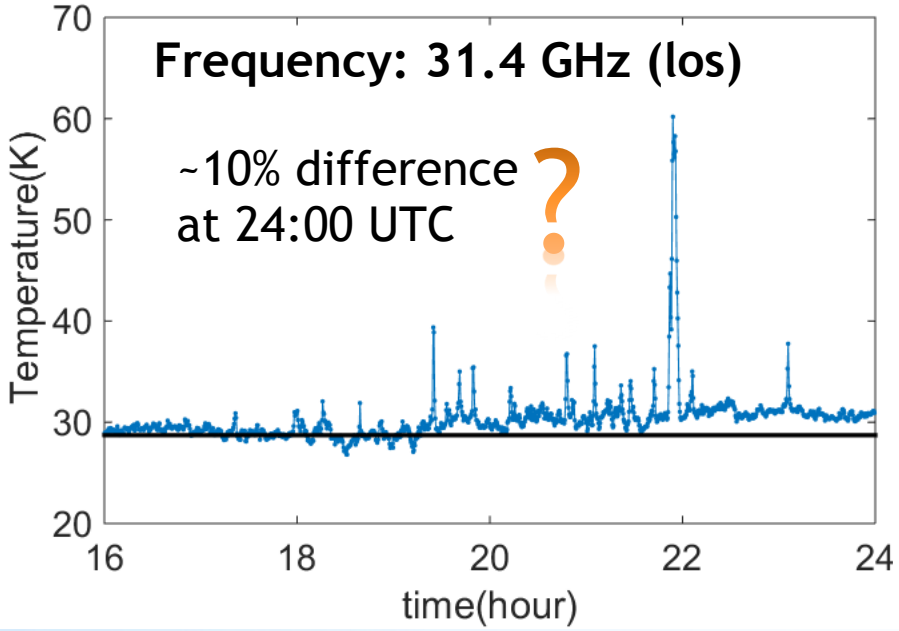
Approximation Radiation Transfer Model

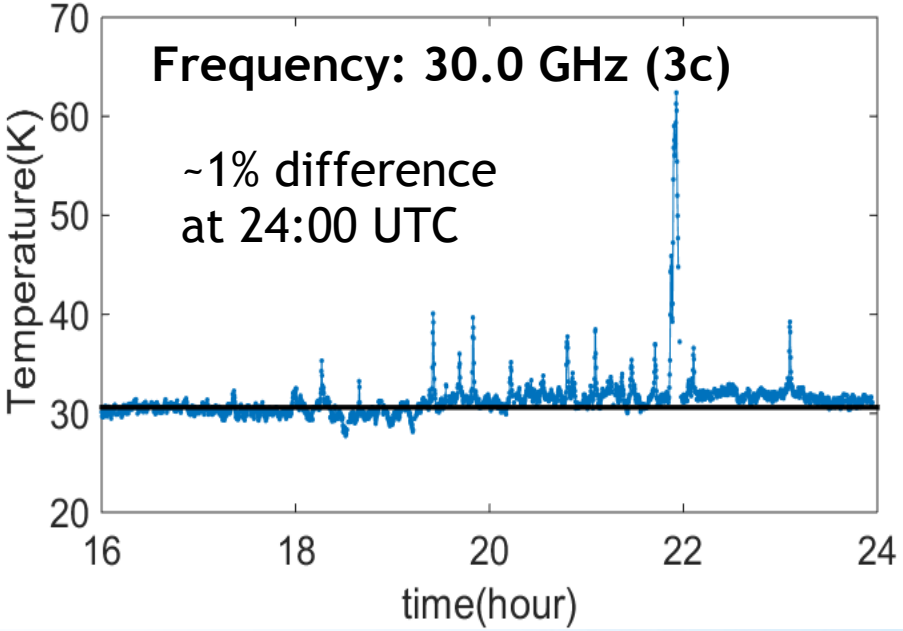


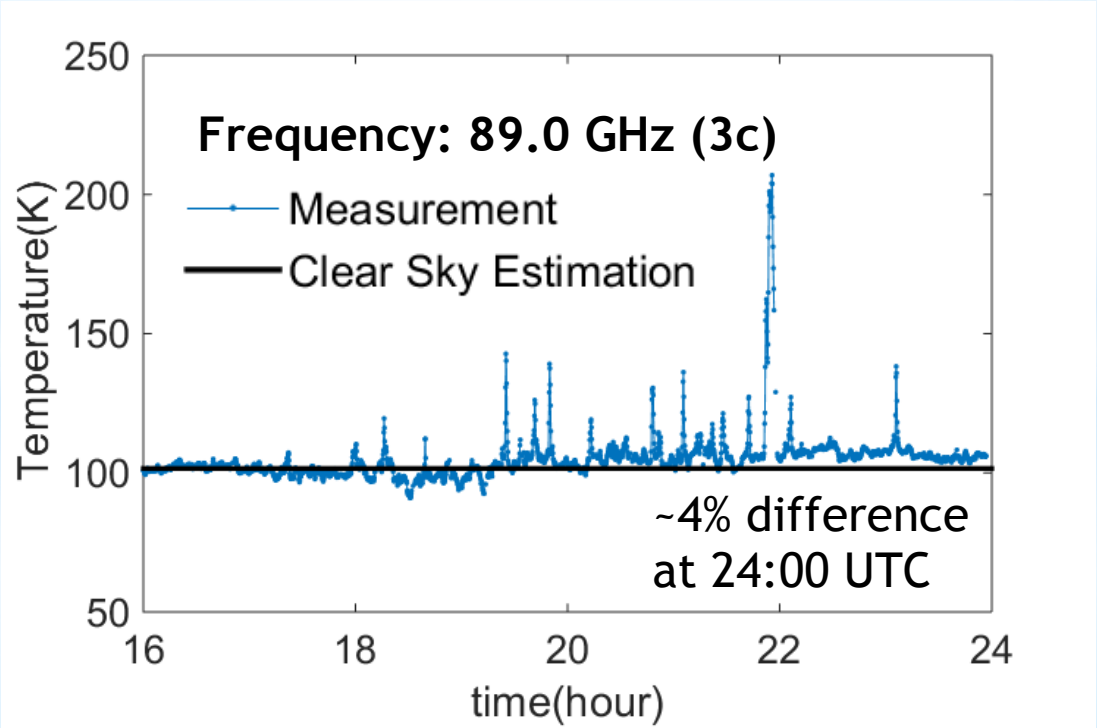

Frequency: 31.4 GHz (los)
Temperature(K)
time(hour)
70
60
50
40
30
20
16
18
20
22
24


Frequency: 30.0 GHz (3c)
Temperature(K)
time(hour)
70
60
50
40
30
20
16
18
20
22
24


Frequency: 89.0 GHz (3c)
Measurement
Clear Sky Estimation
Temperature(K)
time(hour)
250
200
150
100
50
16
18
20
22
24


Frequency: 31.4 GHz (los)
~10% difference
at 24:00 UTC
?
Temperature(K)
time(hour)

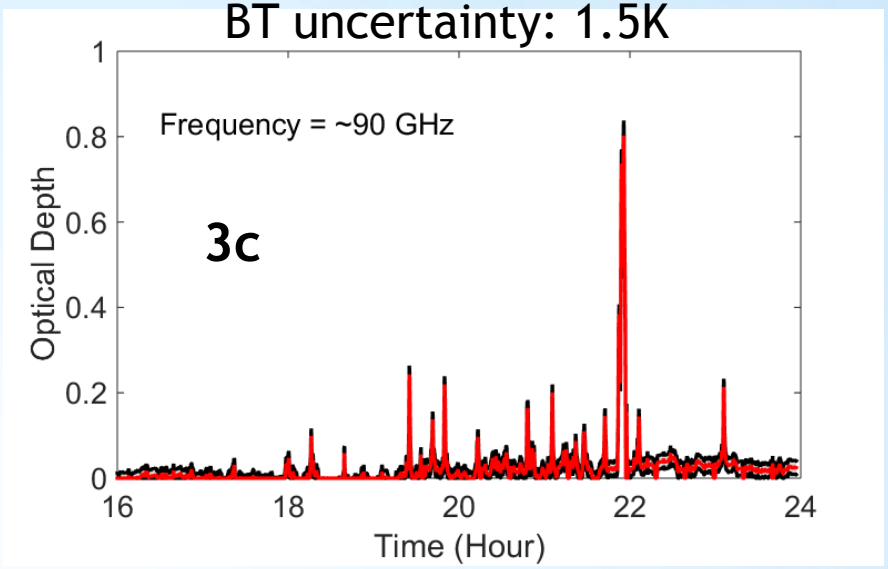

Frequency: 30.0 GHz (3c)
~1% difference
at 24:00 UTC
Temperature(K)
time(hour)


Frequency: 89.0 GHz (3c)
Measurement
Clear Sky Estimation
~4% difference
at 24:00 UTC
Temperature(K)
time(hour)

Estimations of Cloud Optical Depth

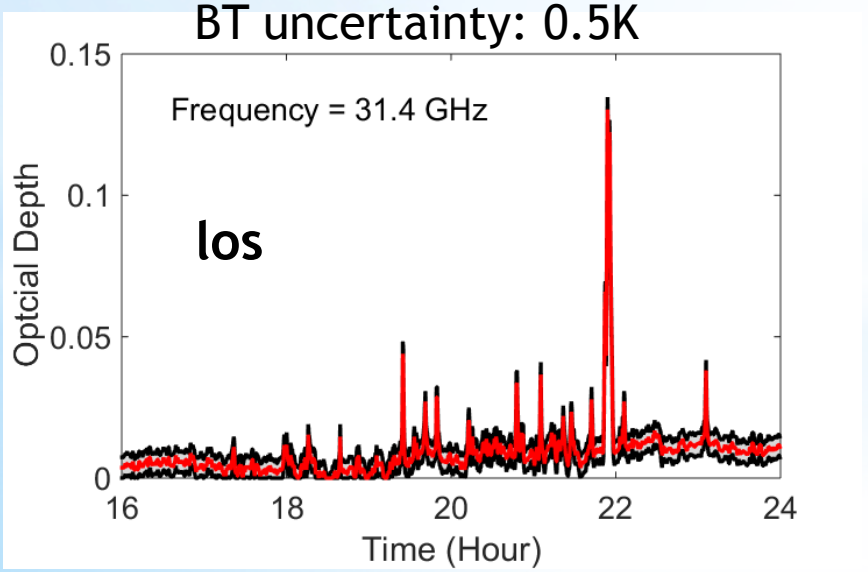
Value
Uncertainty from 2σ BT

BT uncertainty: 1.5K



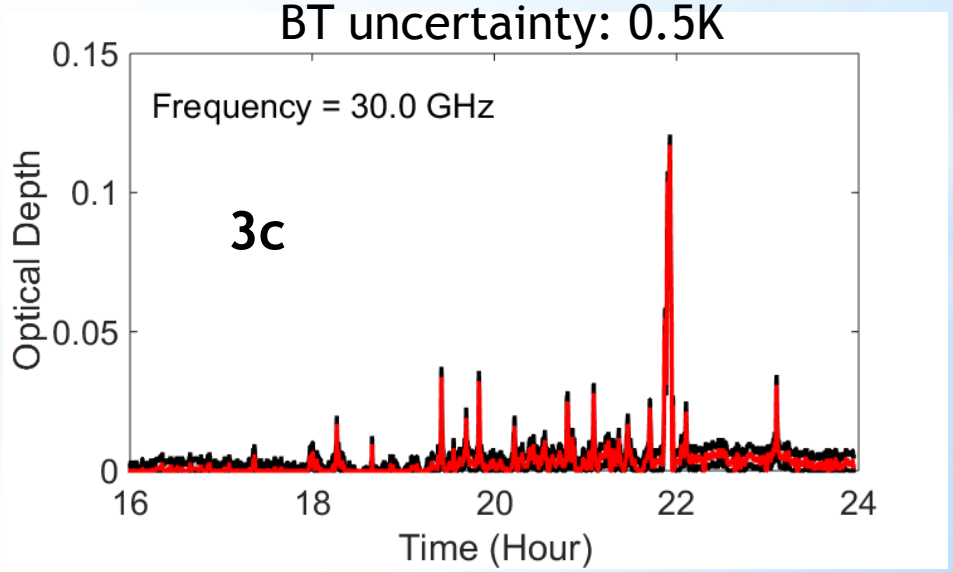
Maximum optical depth uncertainty (0.04)

BT uncertainty: 0.5K



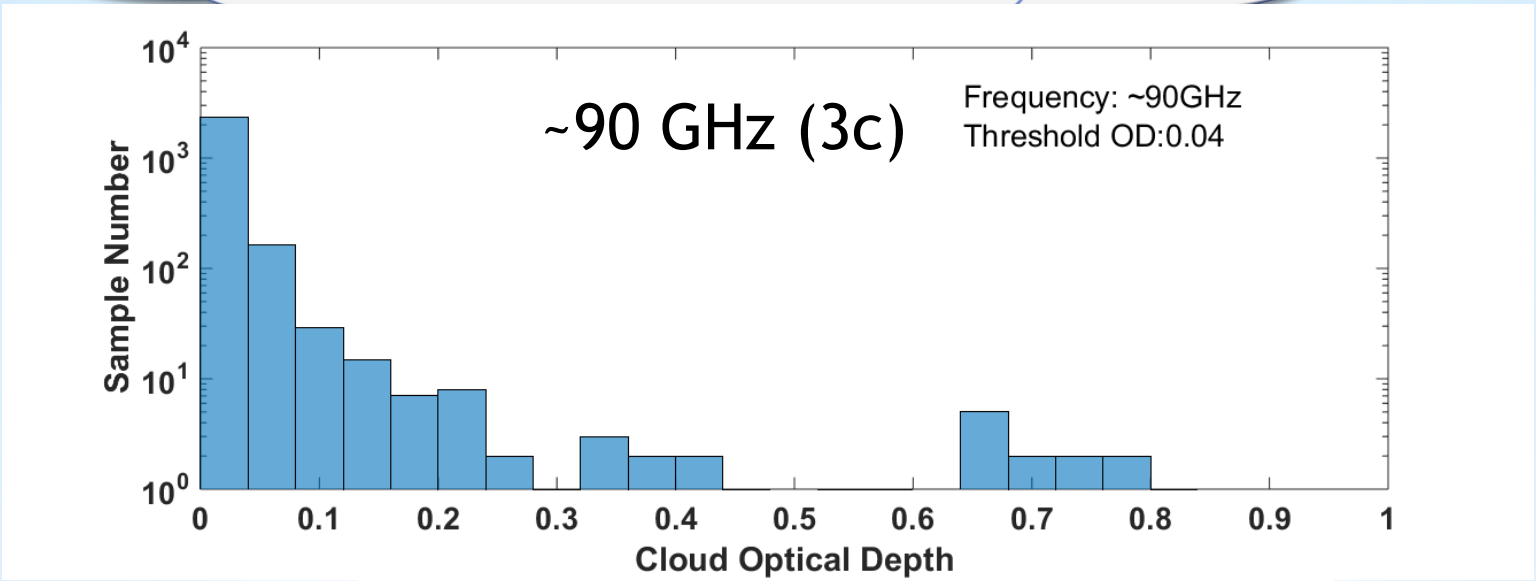
Maximum optical depth uncertainty (0.005)

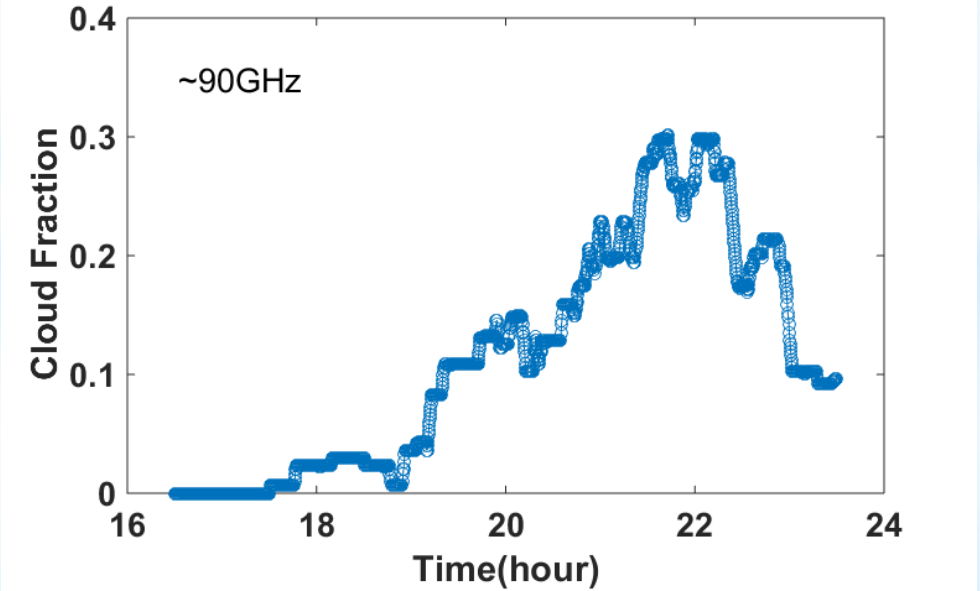
BT uncertainty: 0.5K



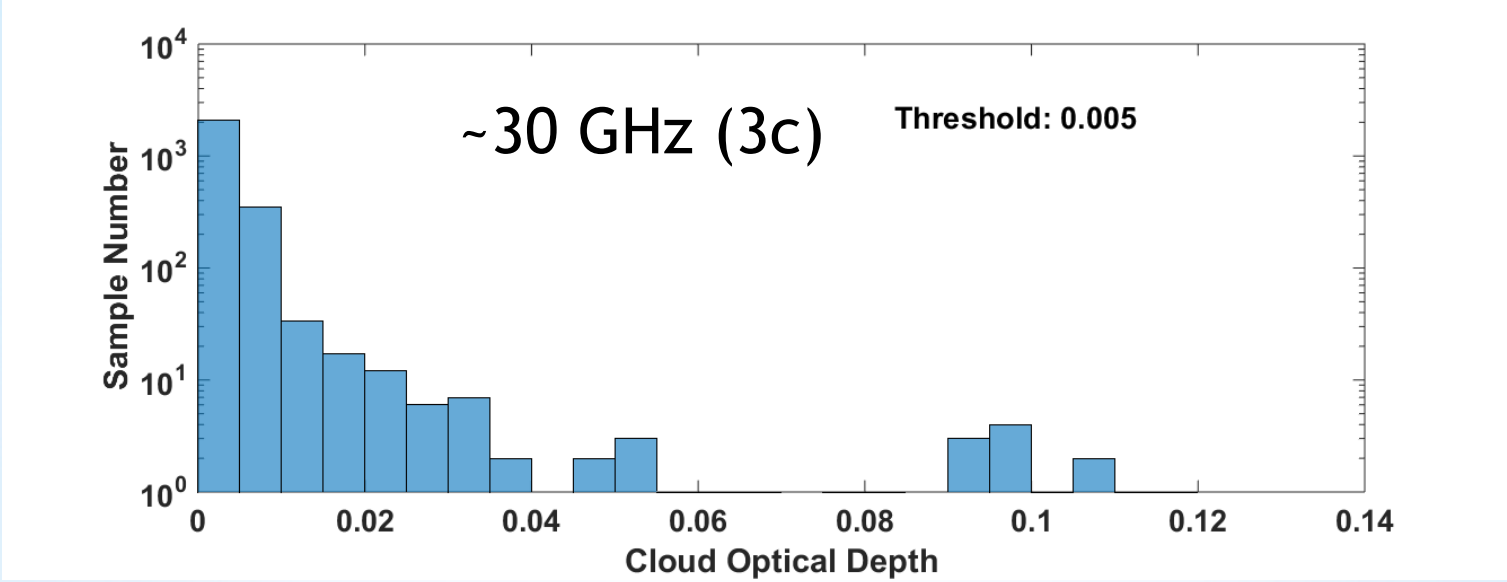
Maximum optical depth uncertainty (0.005)

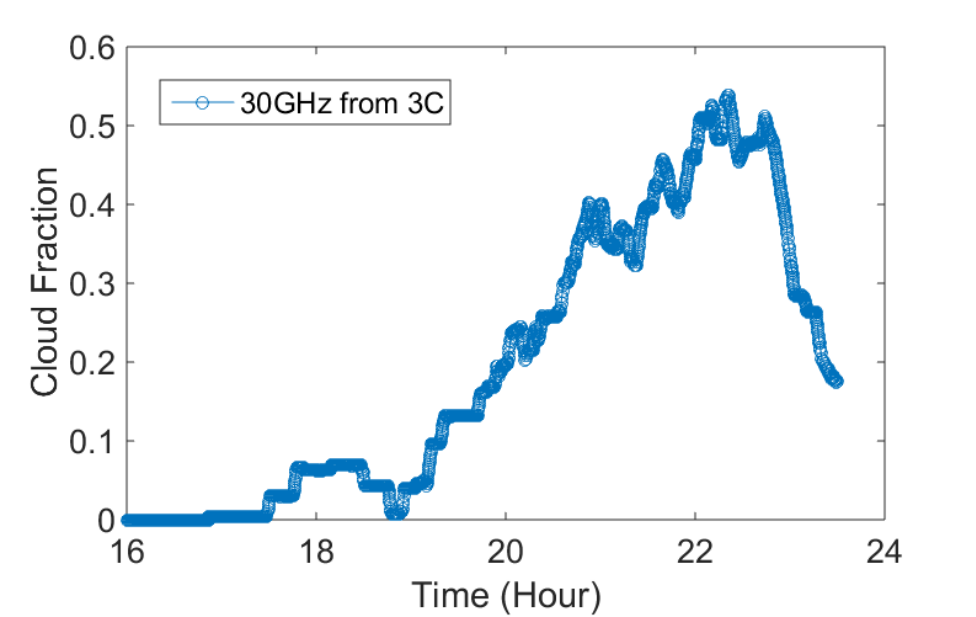
Estimations of Cloud Fraction



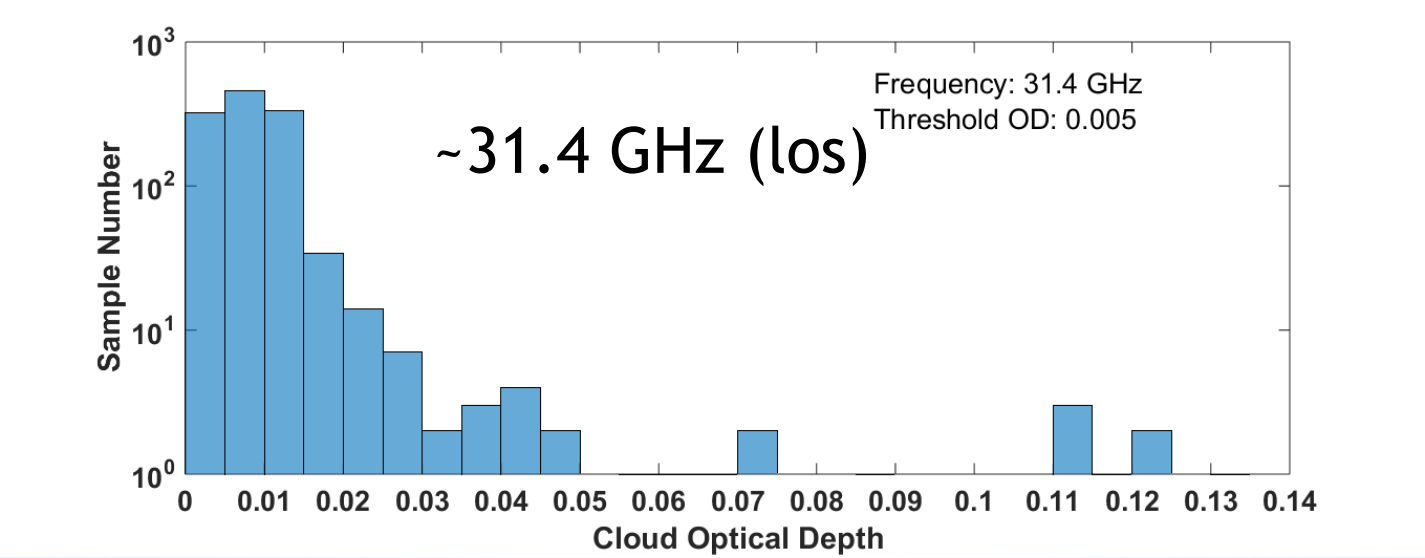


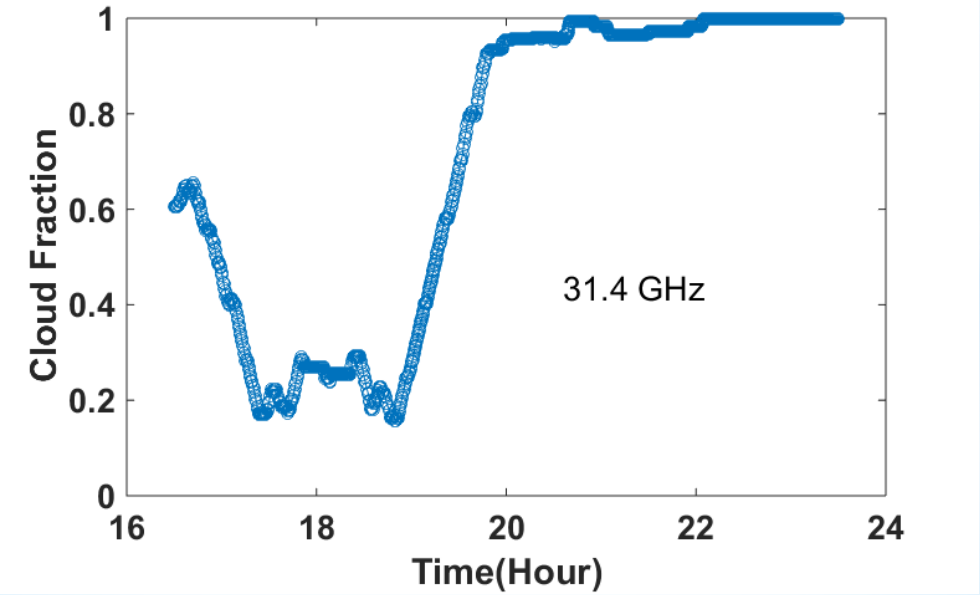
Estimations of Cloud Fraction



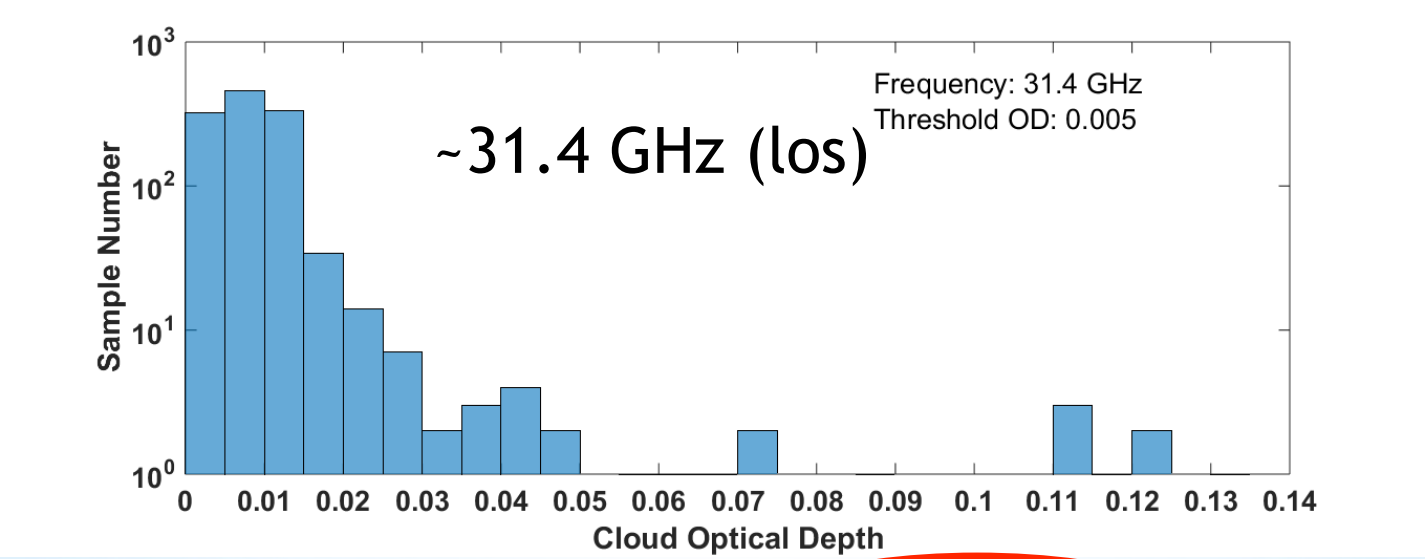


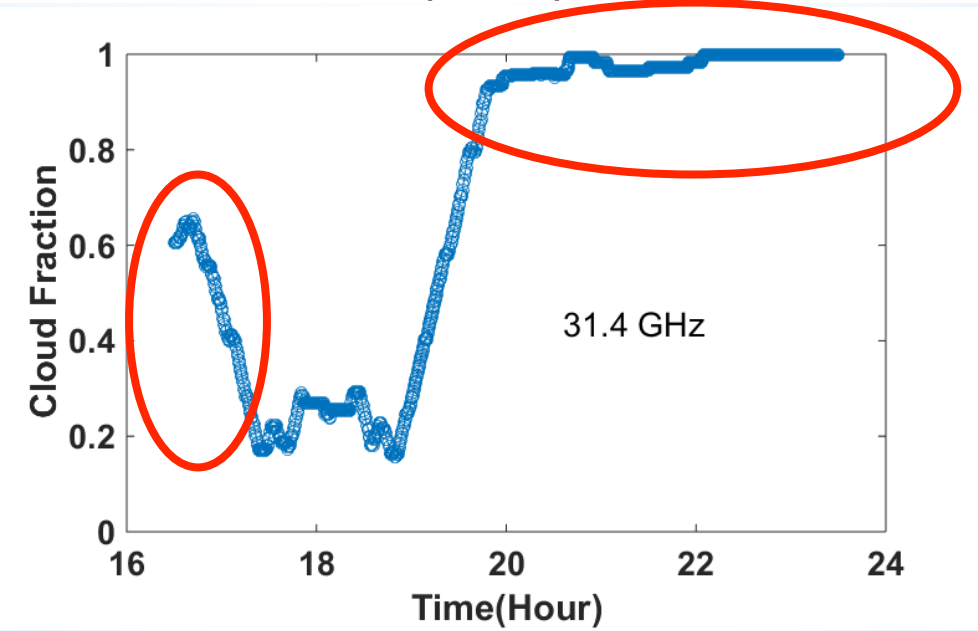
Estimations of Cloud Fraction





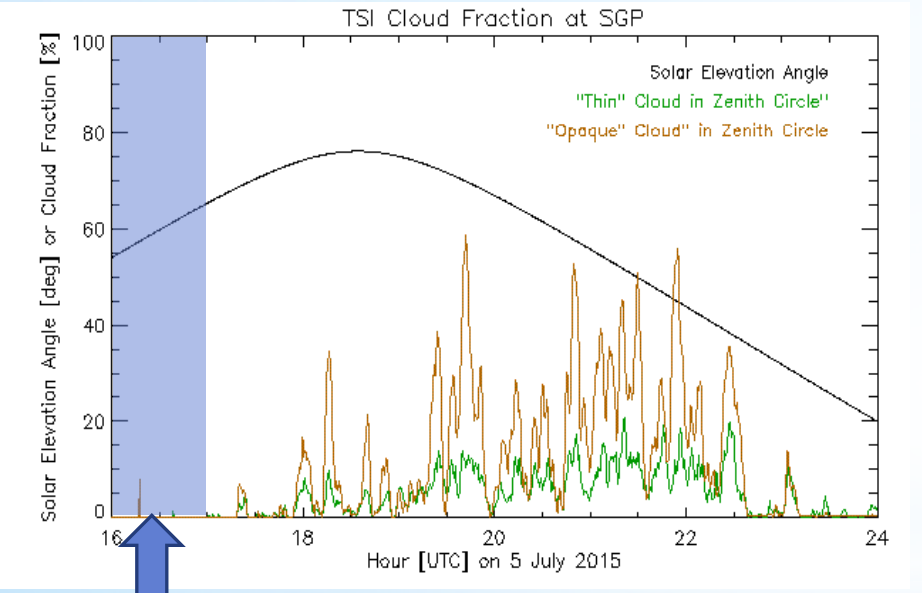
Estimations of Cloud Fraction



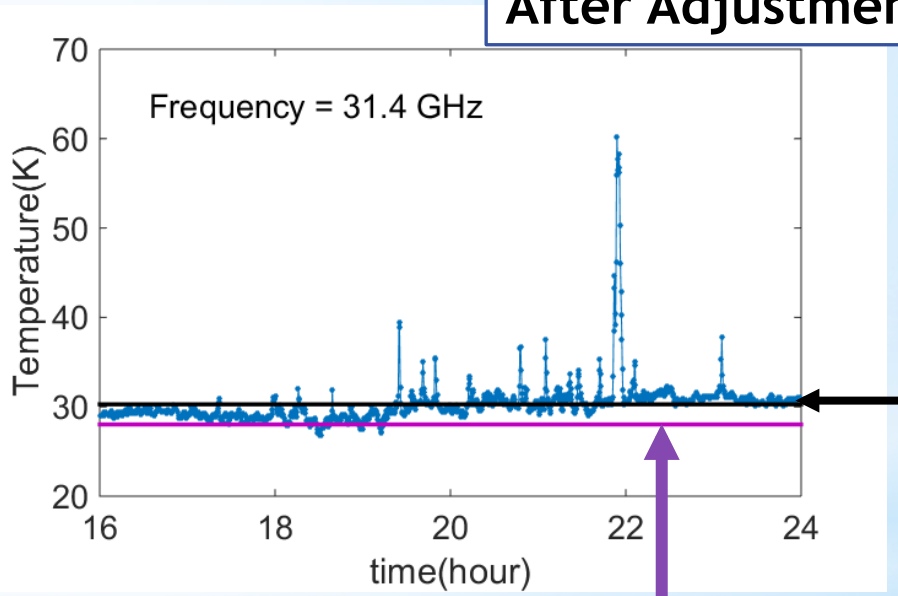


Adjustment of Clear Sky BT (31.4GHz, los)

TSI measurement



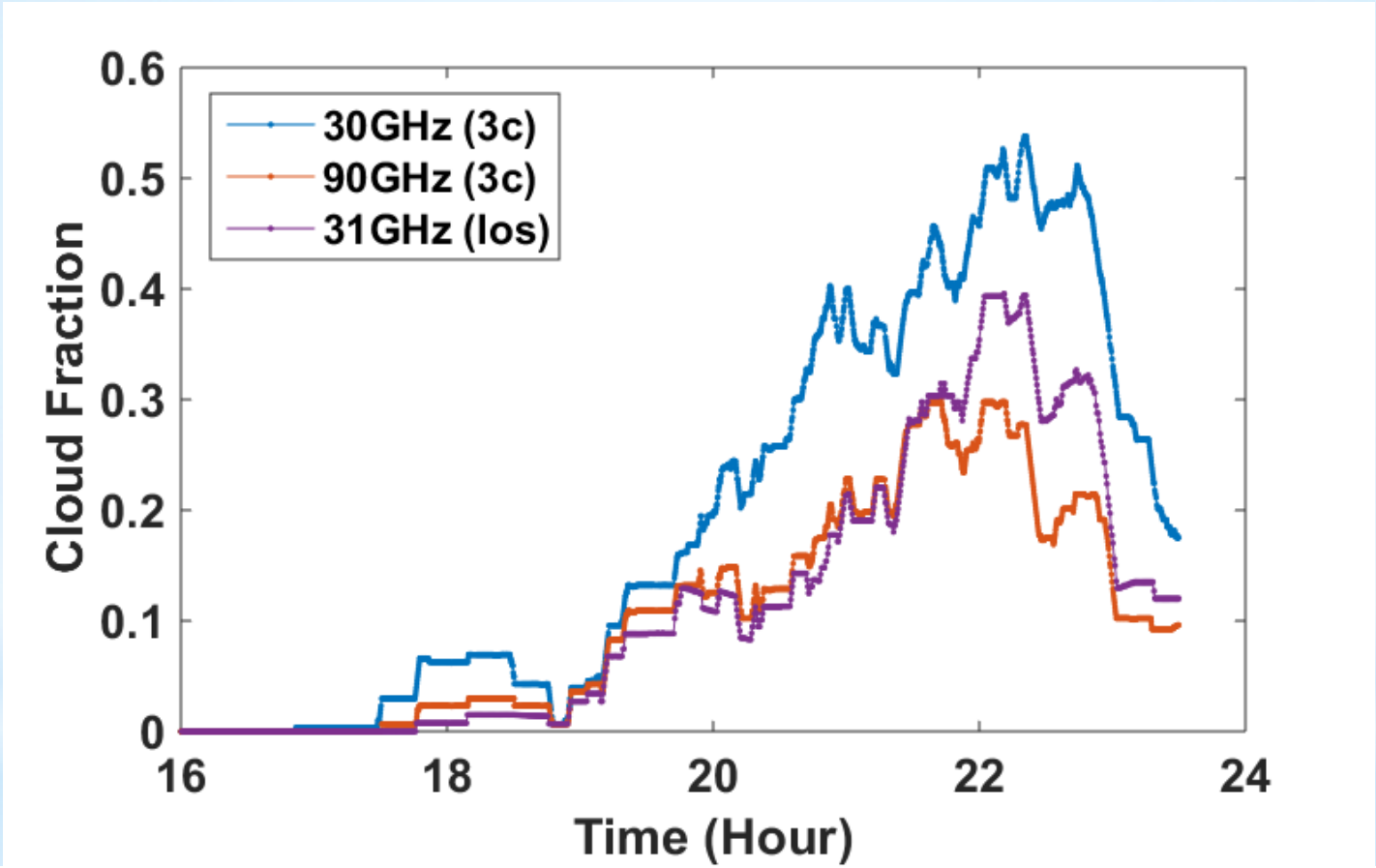
After Adjustment



Before Adjustment

Assumption:
A no cloud region between 16 - 17 (UTC)

After Adjustment



	90 GHz (3c)	30 GHz (3c)	31.4GHz (los)
Threshold	0.04	0.005	0.0125

Micropulse Lidar

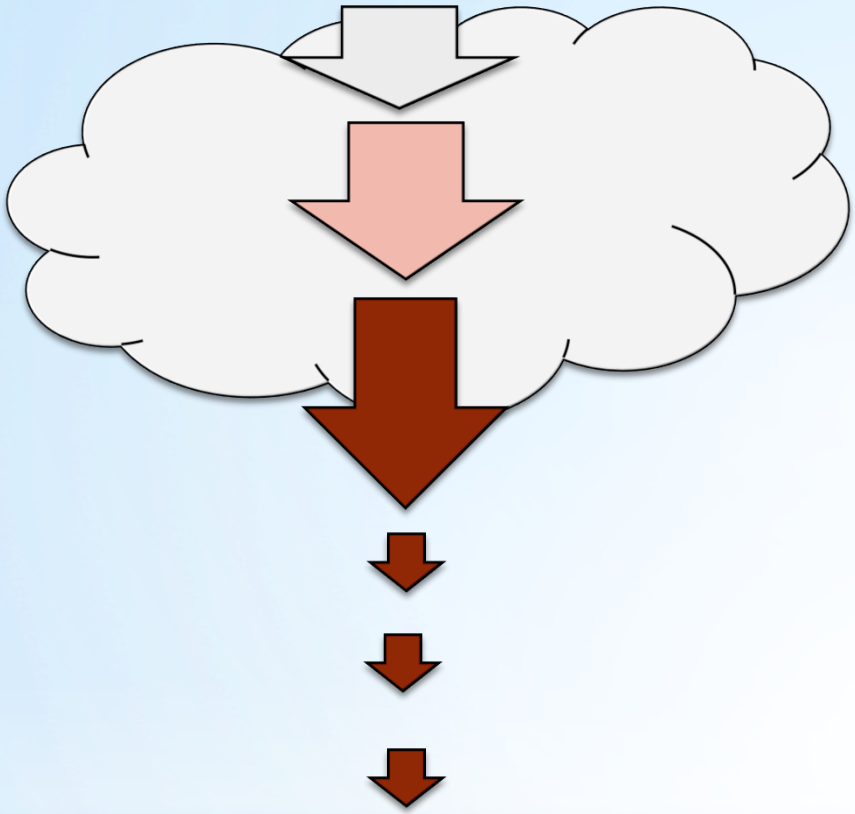
George had to leave ☹


CAUTION


CAUTION


CAUTION


CAUTION



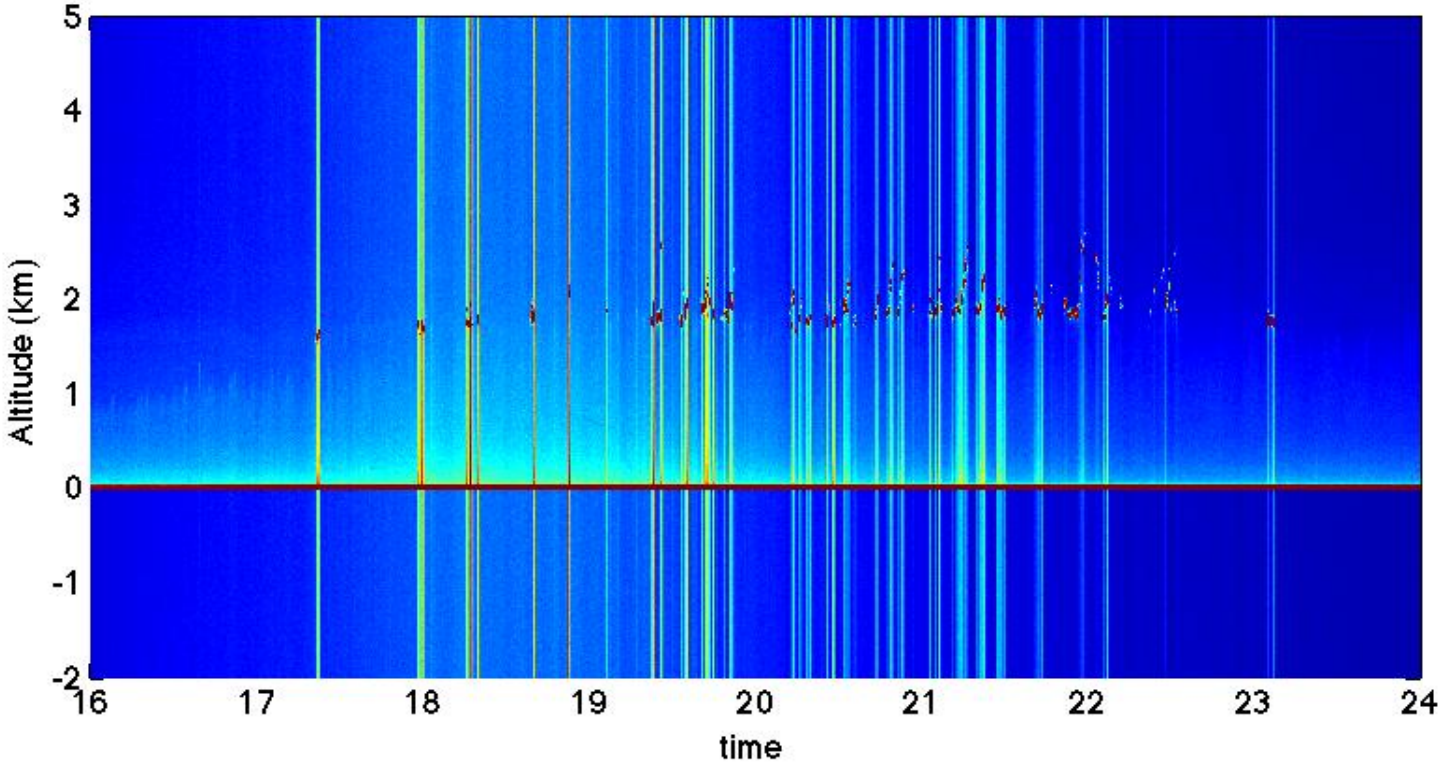

CAUTION


CAUTION

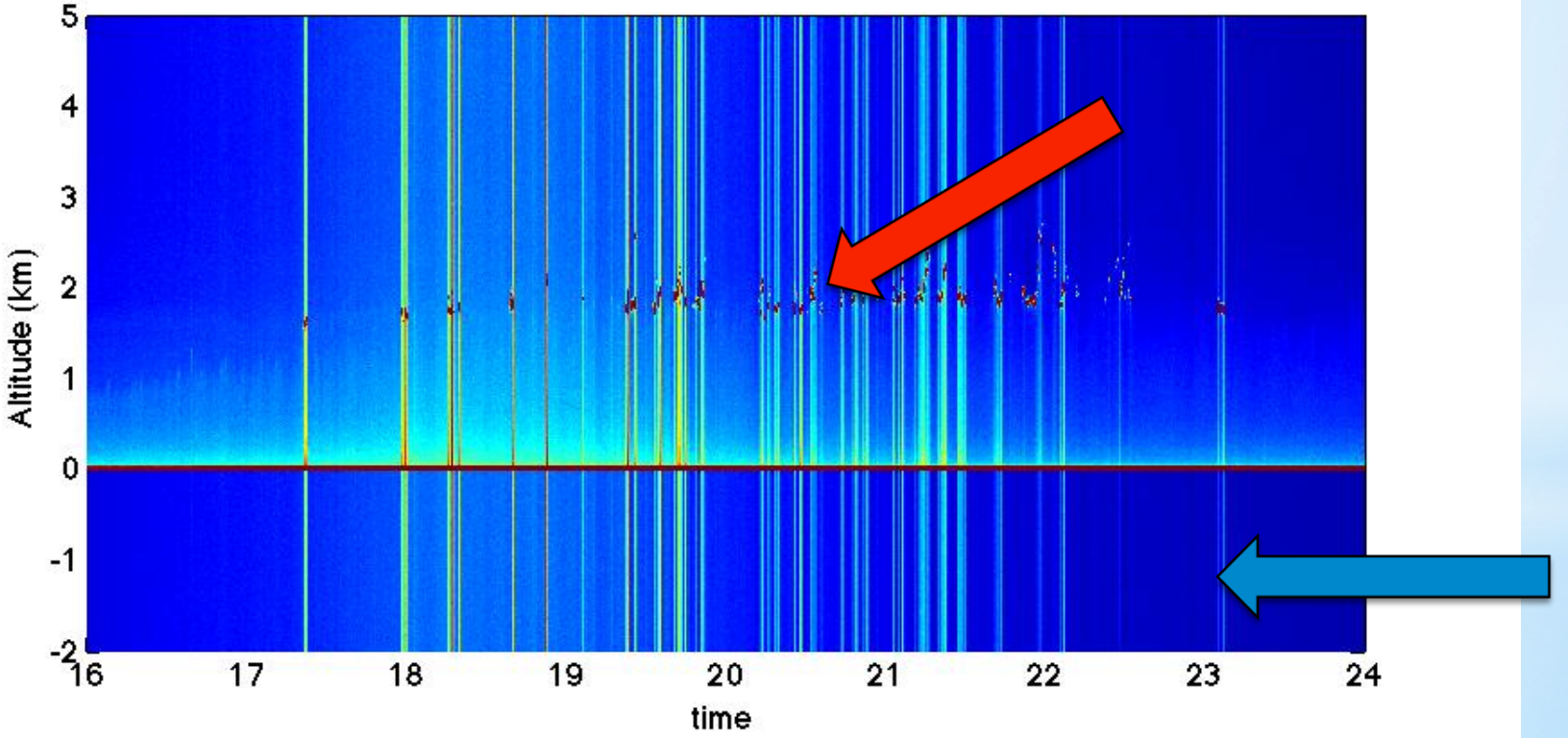

CAUTION

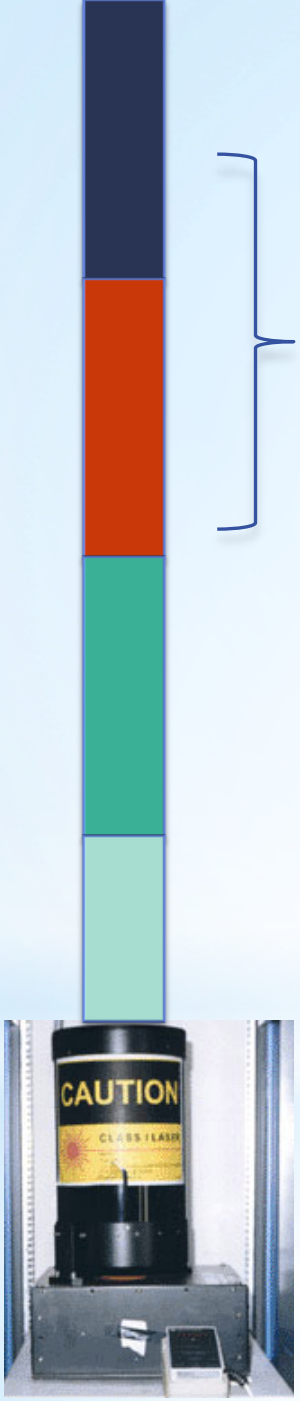

CAUTION

Micropulse Lidar

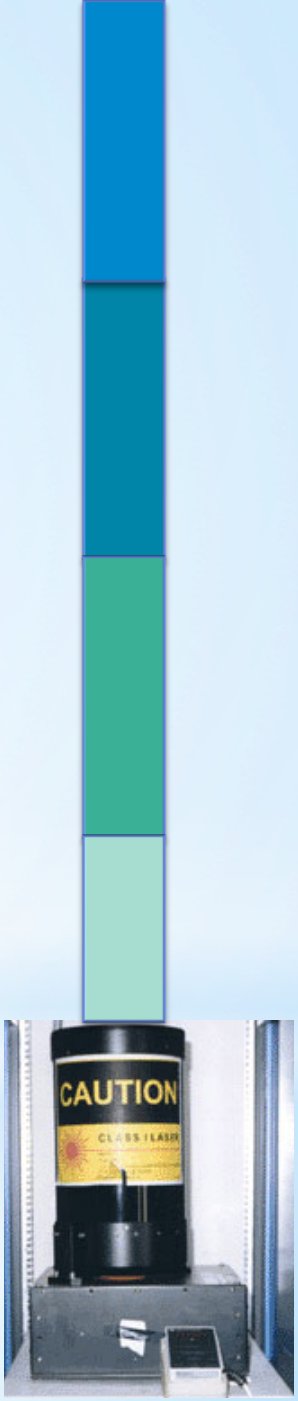


Micropulse Lidar

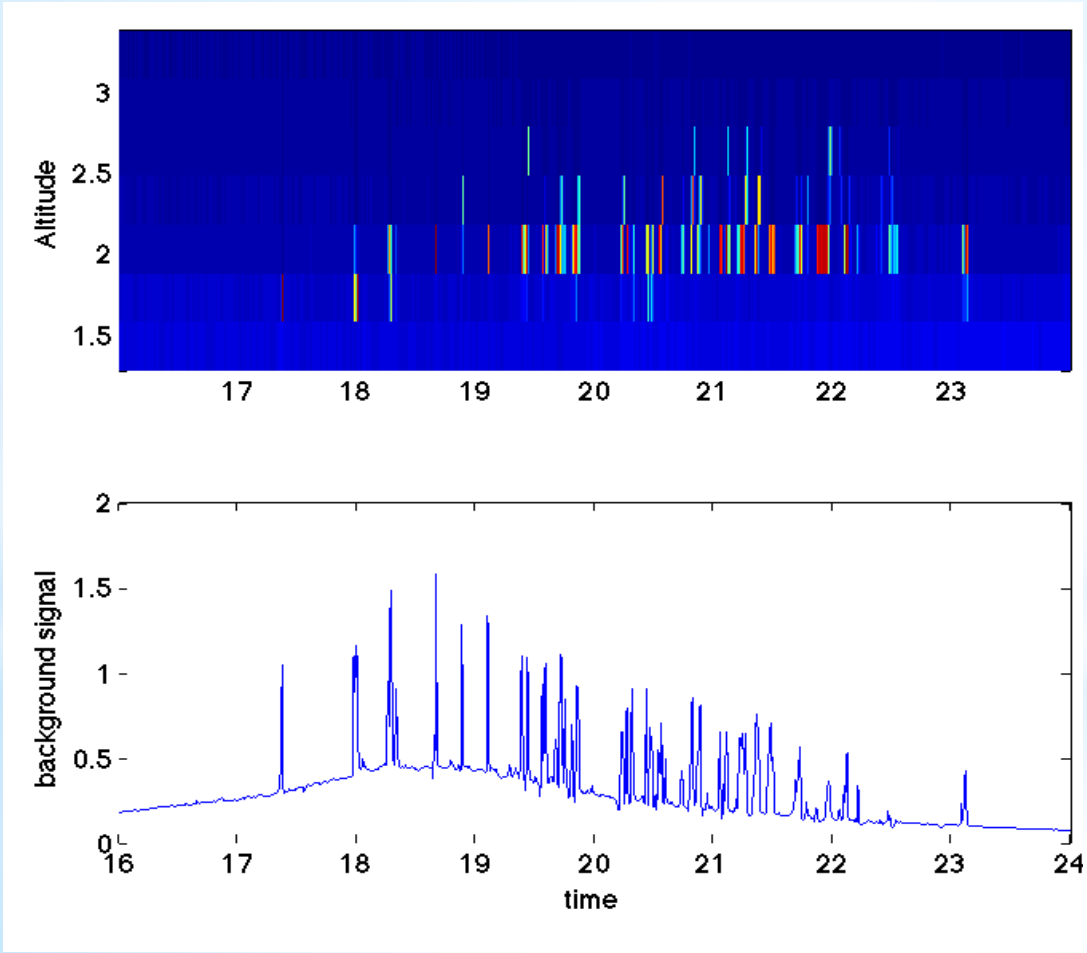




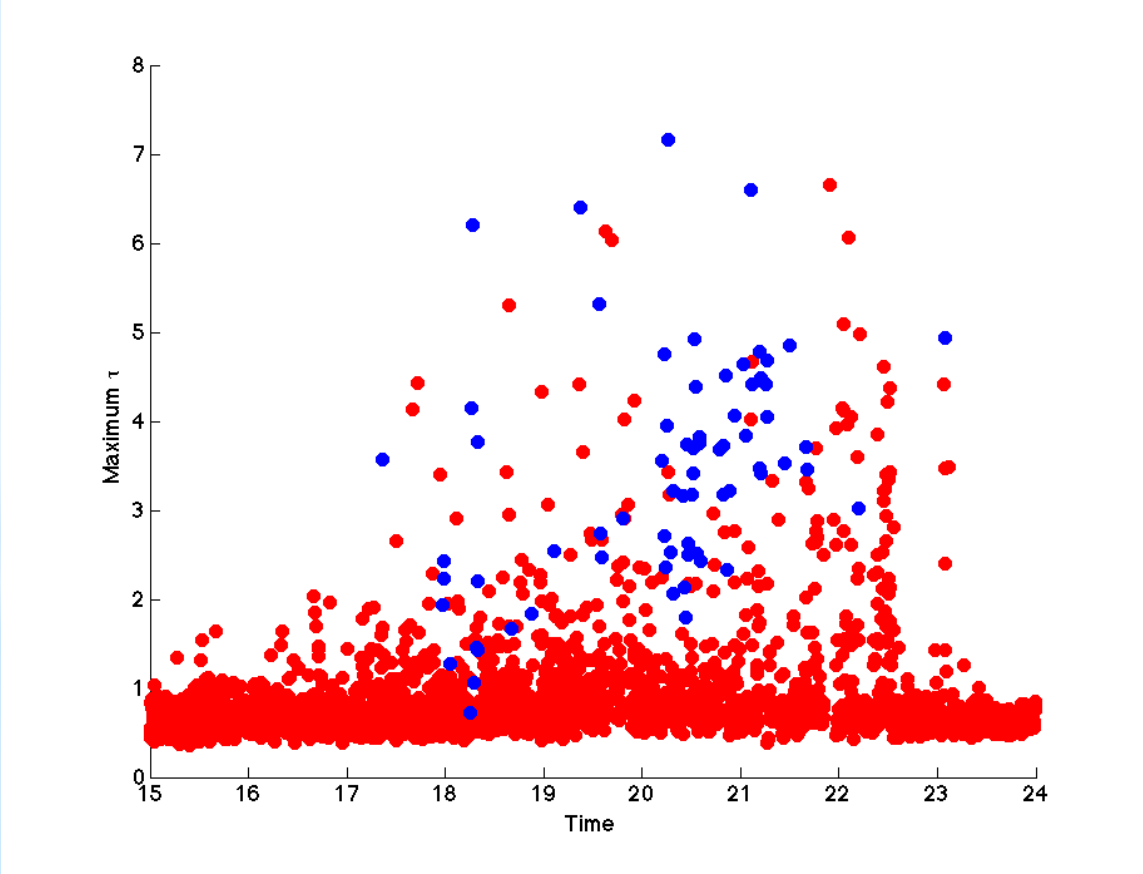
$$\tau = -\ln\left(\frac{I}{I_o}\right)$$



Micropulse Lidar

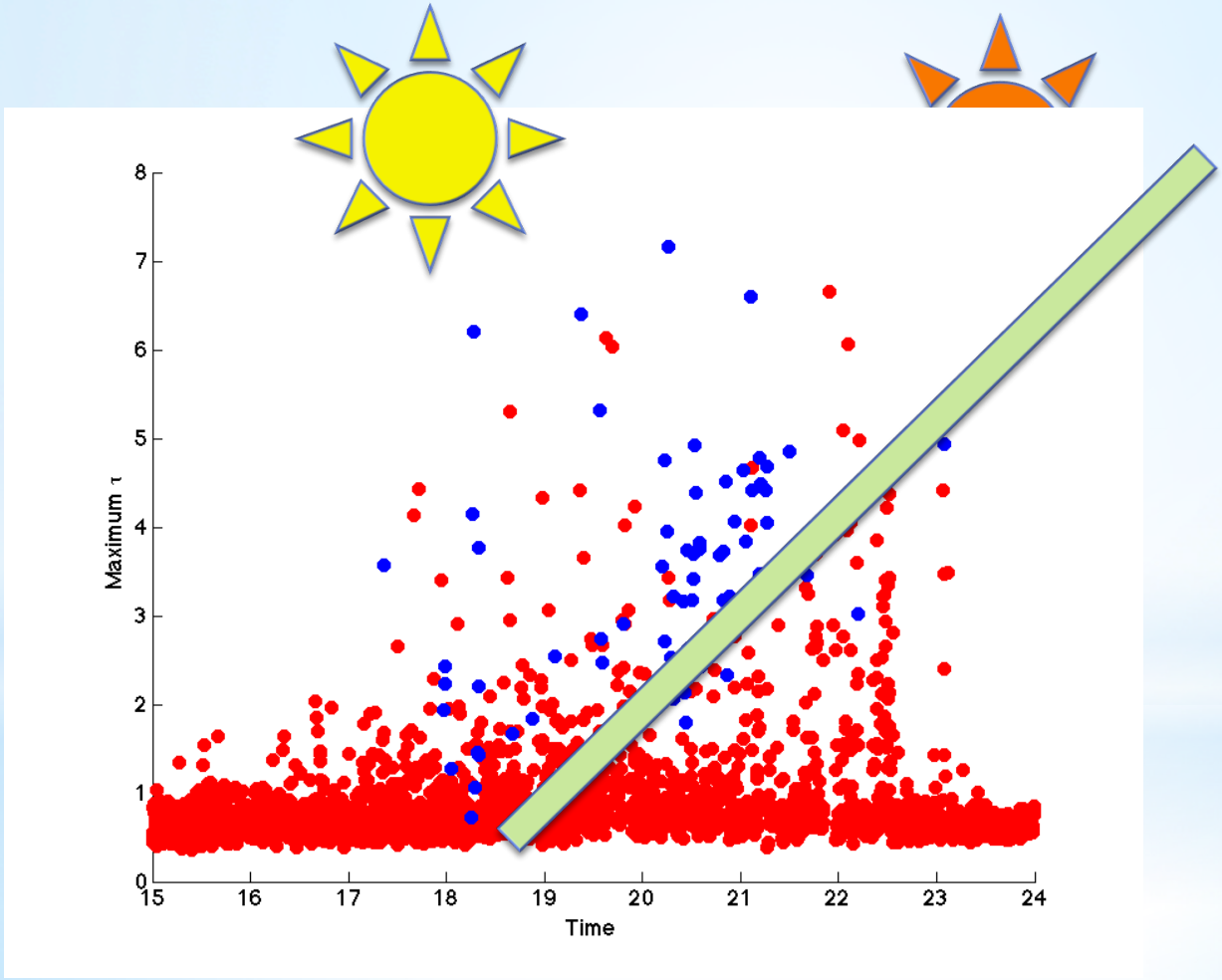


Micropulse Lidar



Background and Active
Just Active

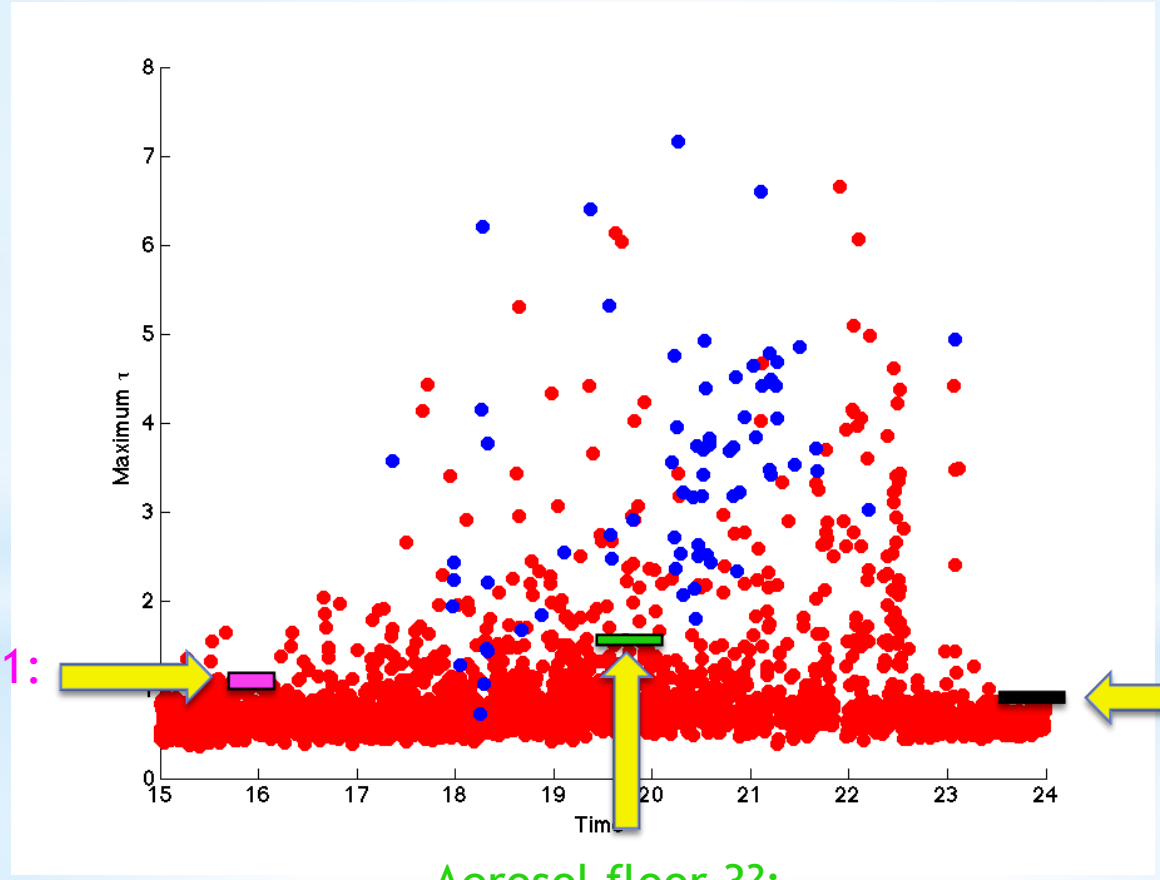
Micropulse Lidar



Background and Active

Just Active

Micropulse Lidar

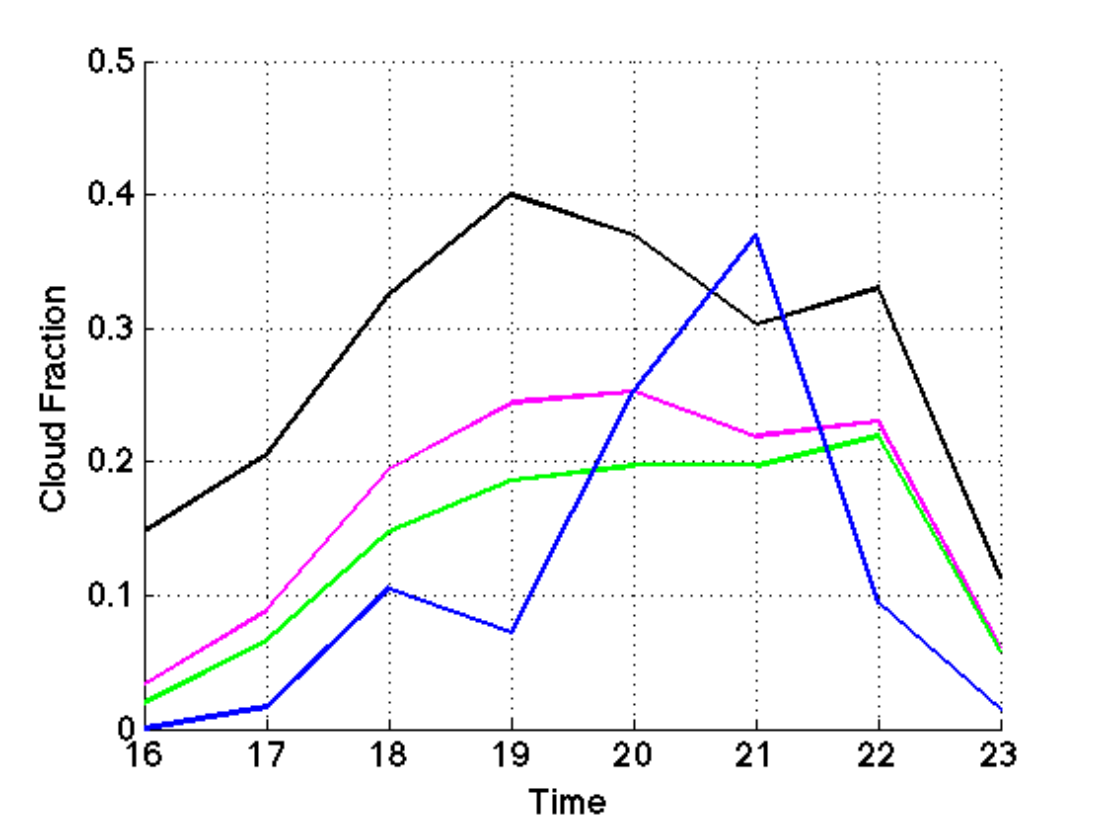


Aerosol floor 1: 1.06

Aerosol floor 1: 0.85

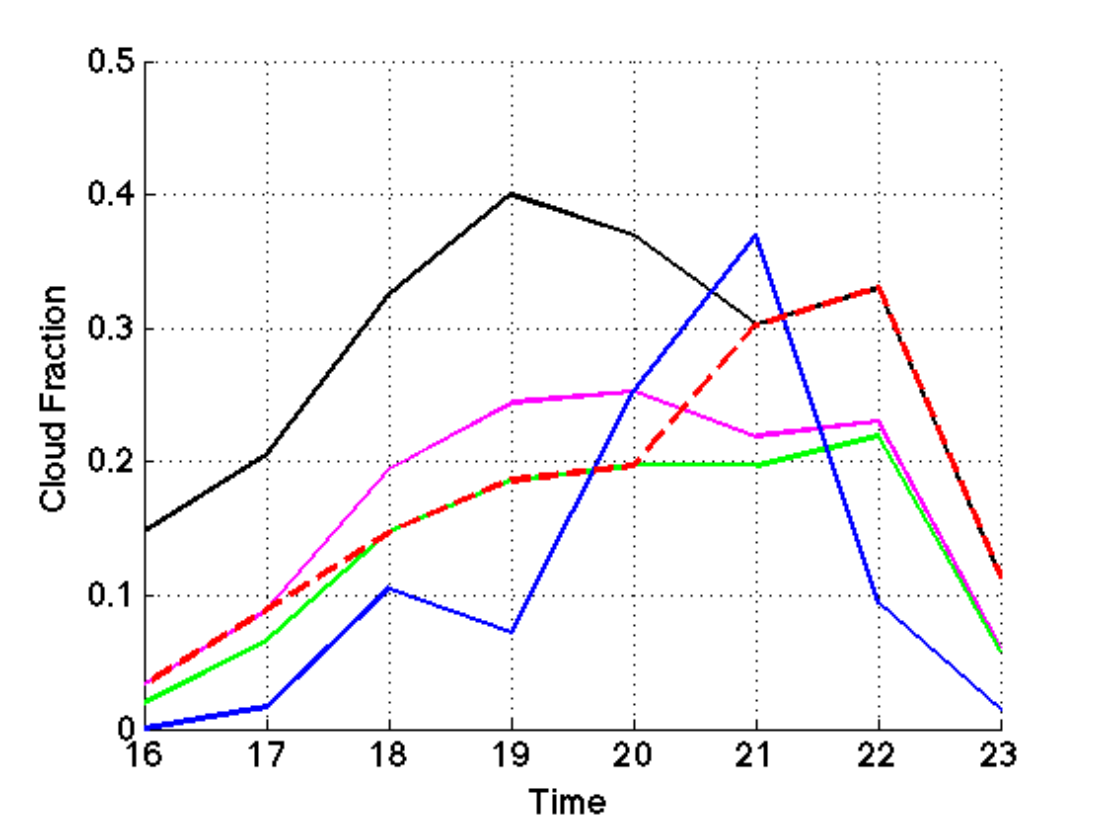
Aerosol floor 3?: 1.16

Micropulse Lidar



Aerosol floor: morning
Aerosol floor: noon
Aerosol floor: night
Background

Micropulse Lidar



Aerosol floor: morning
Aerosol floor: noon
Aerosol floor: night
Background
Parameterized

KAZR

Ceilometer

First look of the KAZR output

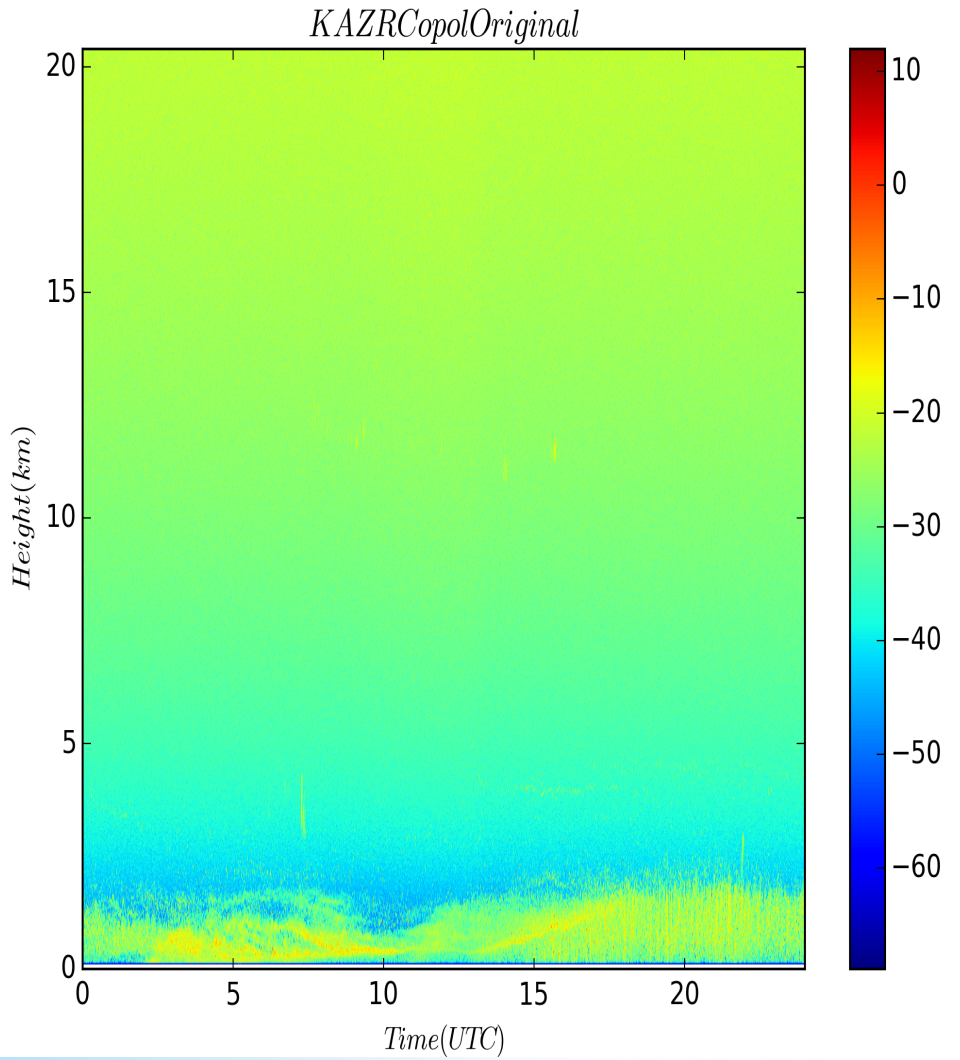


Fig. 1a Cloud reflectivity copol mode

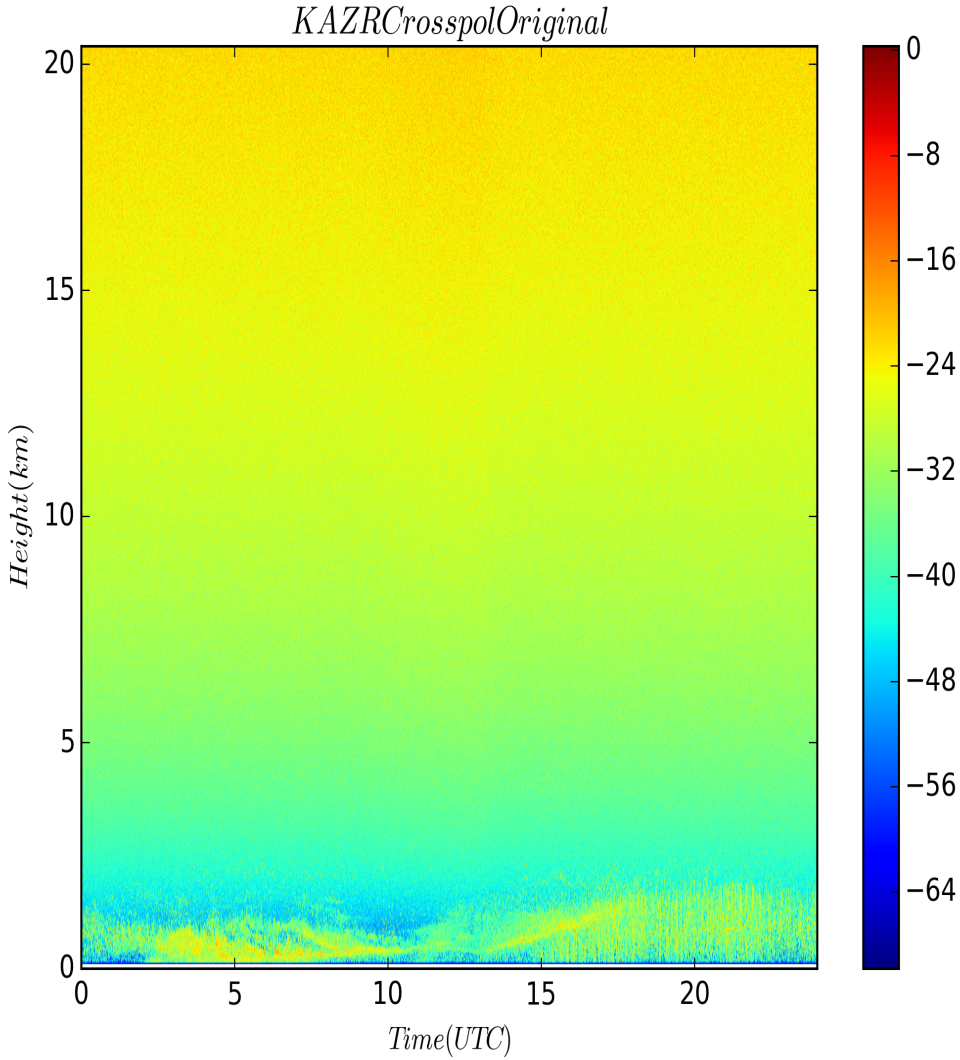


Fig.1b Cloud reflectivity crosspol mode

First look of the KAZR output

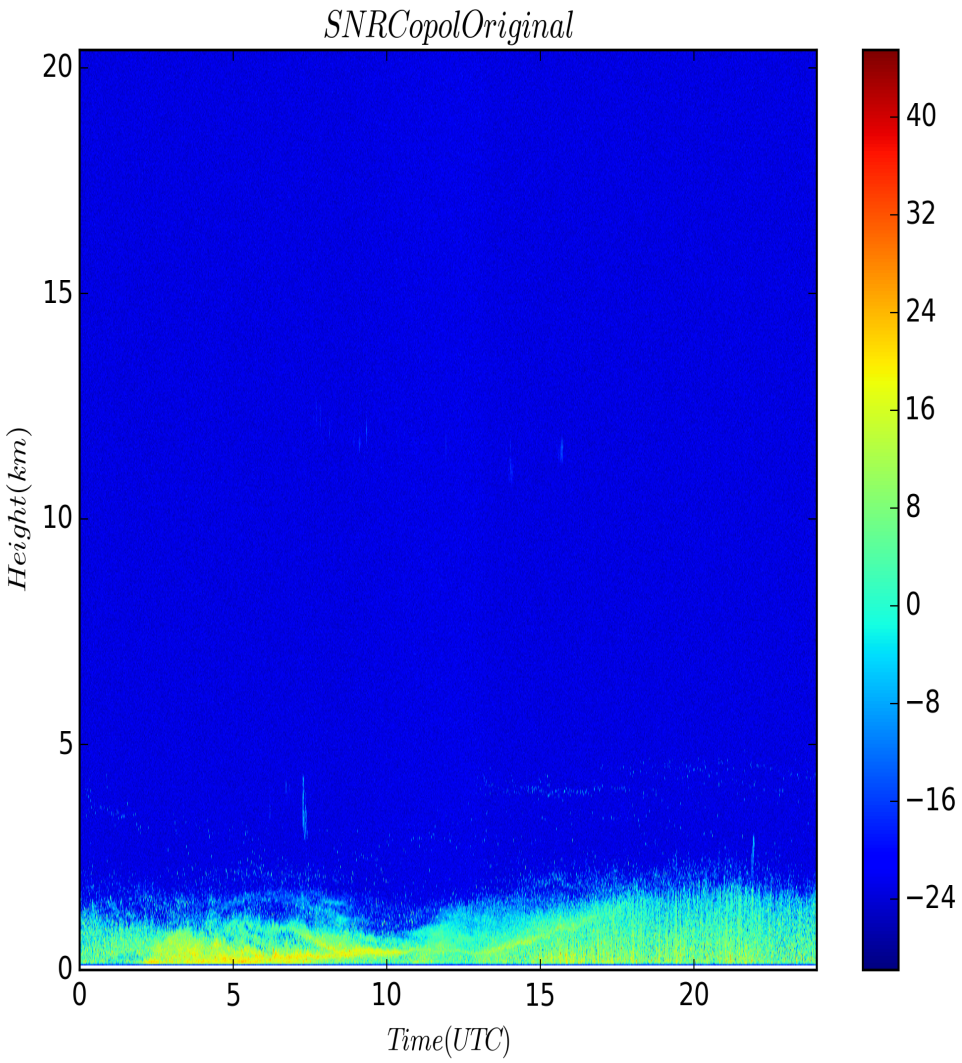


Fig. 2a Cloud SNR copol mode

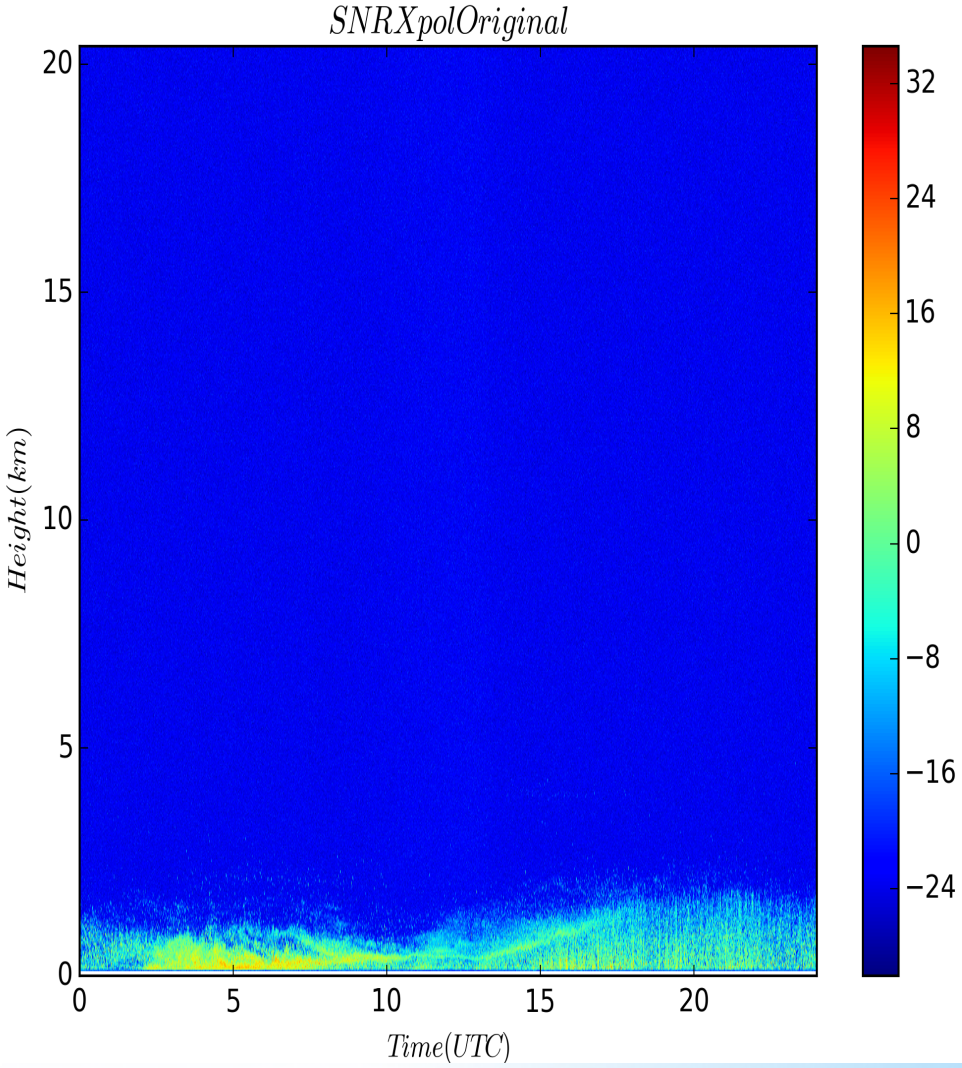


Fig.2b Cloud SNR crosspol mode

Filter the background noise-Step one

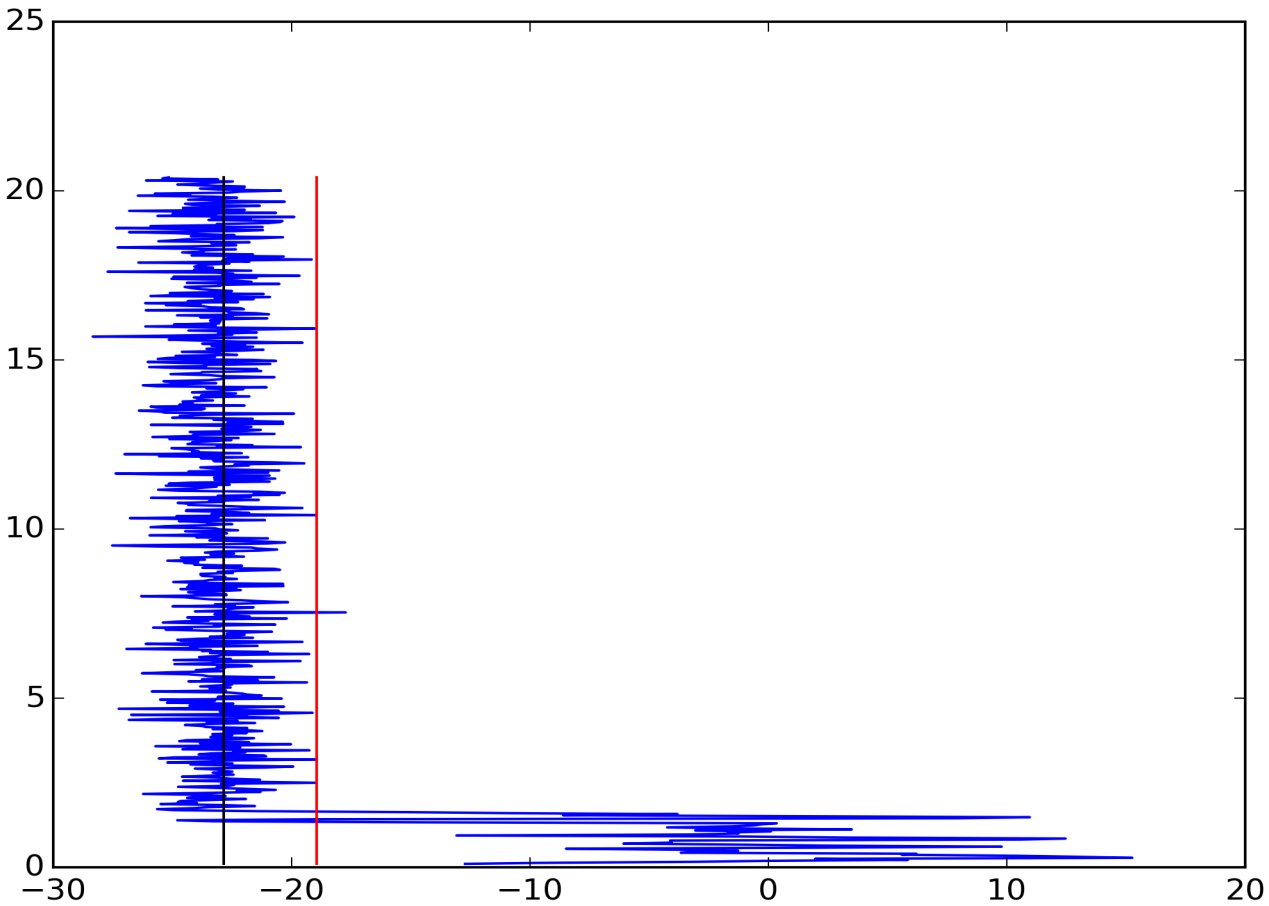


Fig.3 Mean noise level, maximum noise level of one specific time profile
Courtesy of Pavlos for the code for this

Filter the background noise-Step two

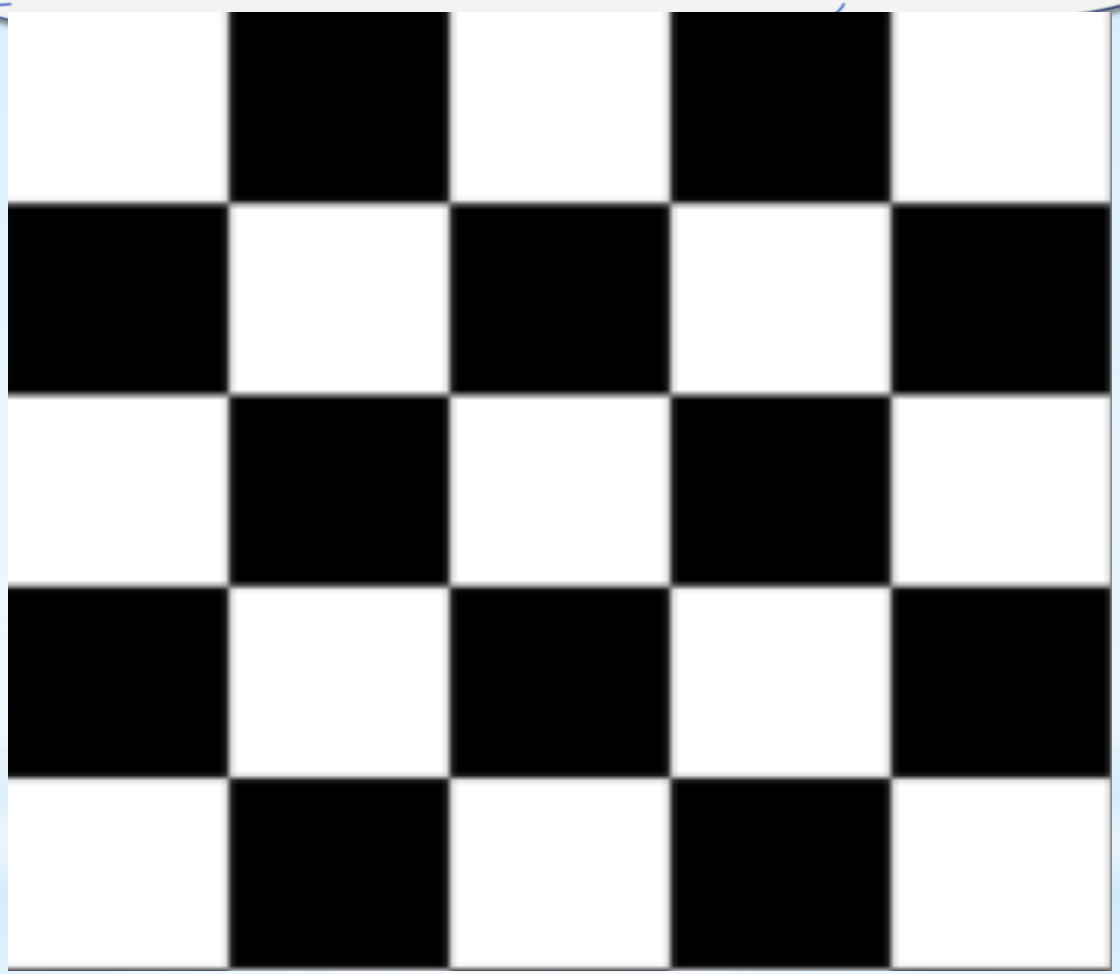
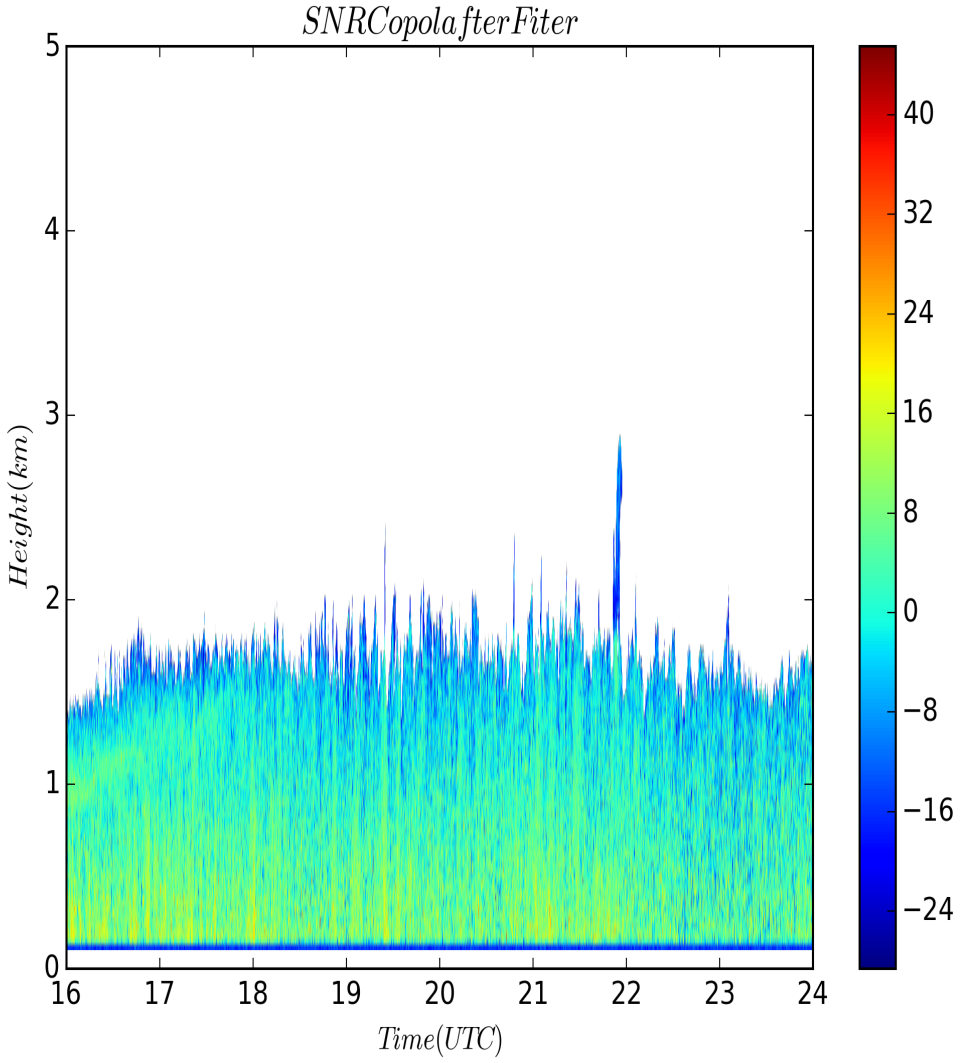


Fig.4 Chess board voting for cloud---2-D cloud mask (Clothiaux et al. 2000)

Filter the background noise-result



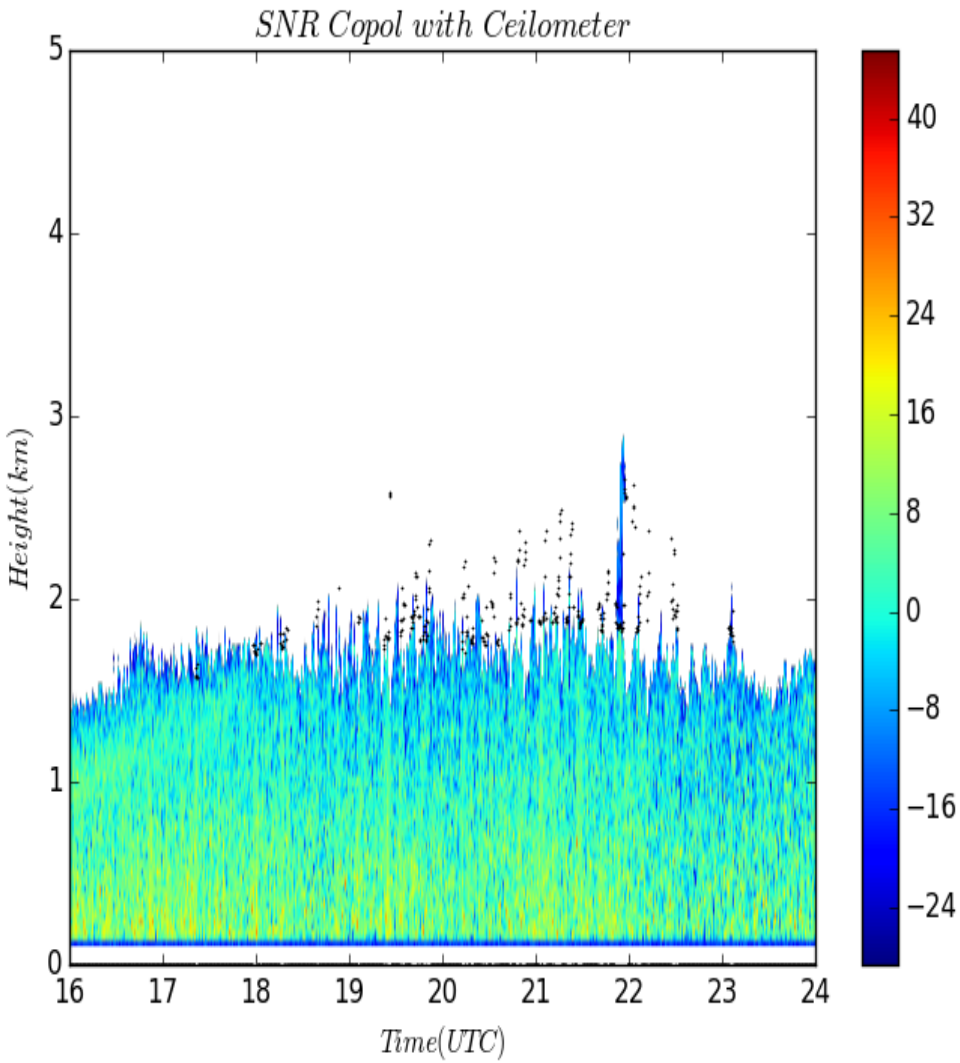


Fig.5a Copol SNR after cloud mask Fig.5b Copol SNR after cloud mask with ceilometer

Filter the background noise-result

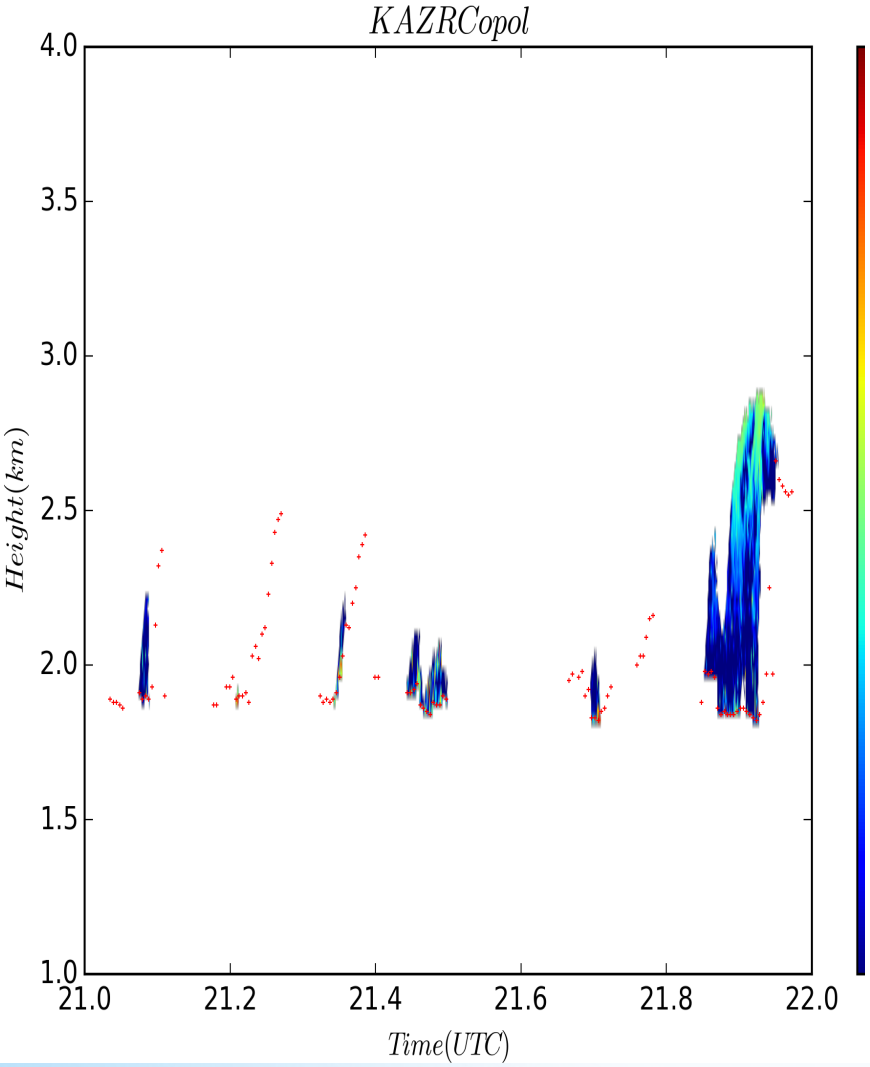


Fig.6a Final 'real cloud' reflectivity

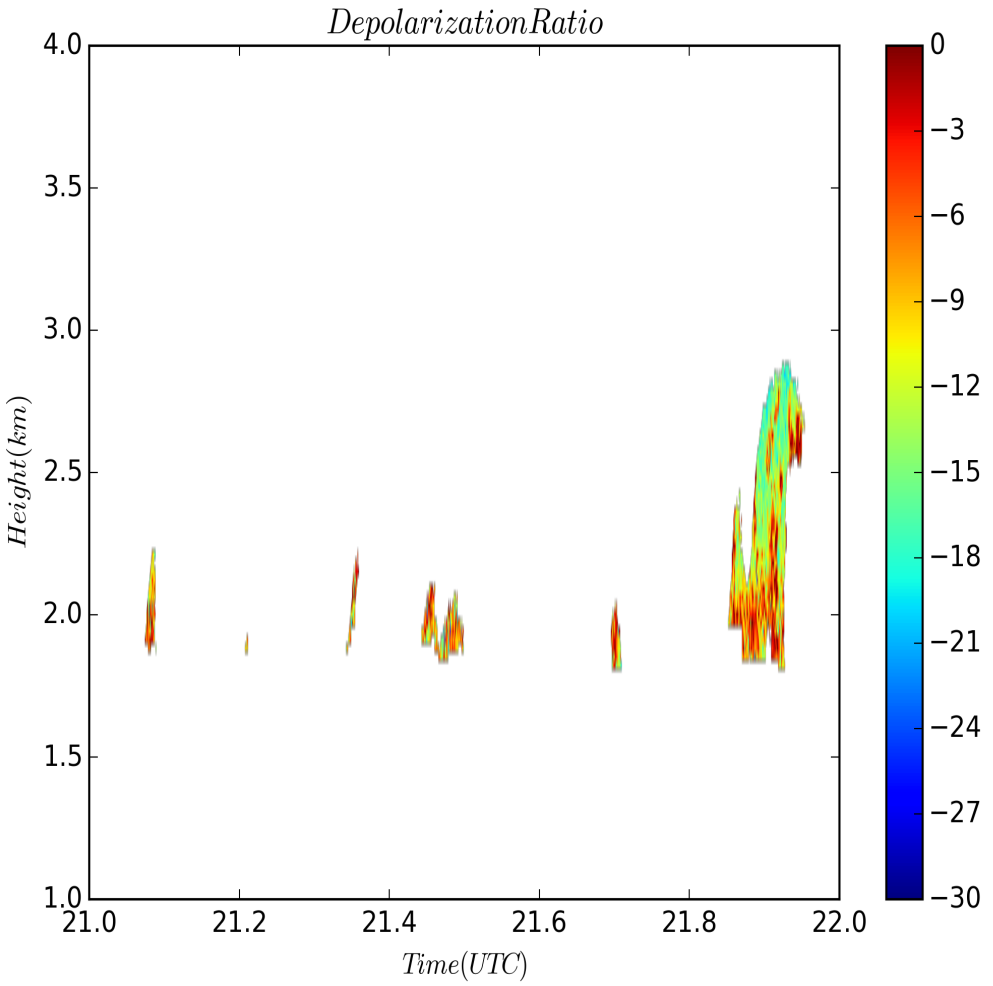


Fig.6b Final fake LDR

Filter the background noise-result

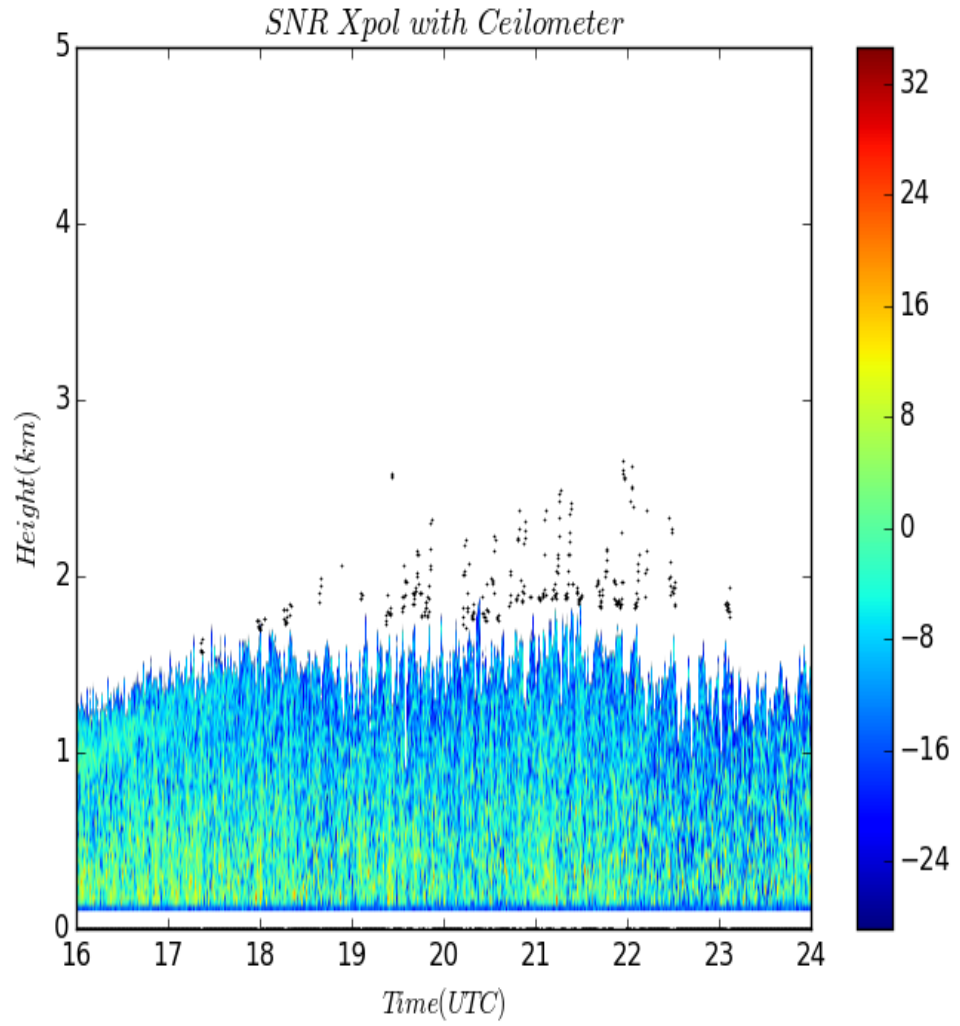


Fig.7a Final ‘real cloud’ reflectivity

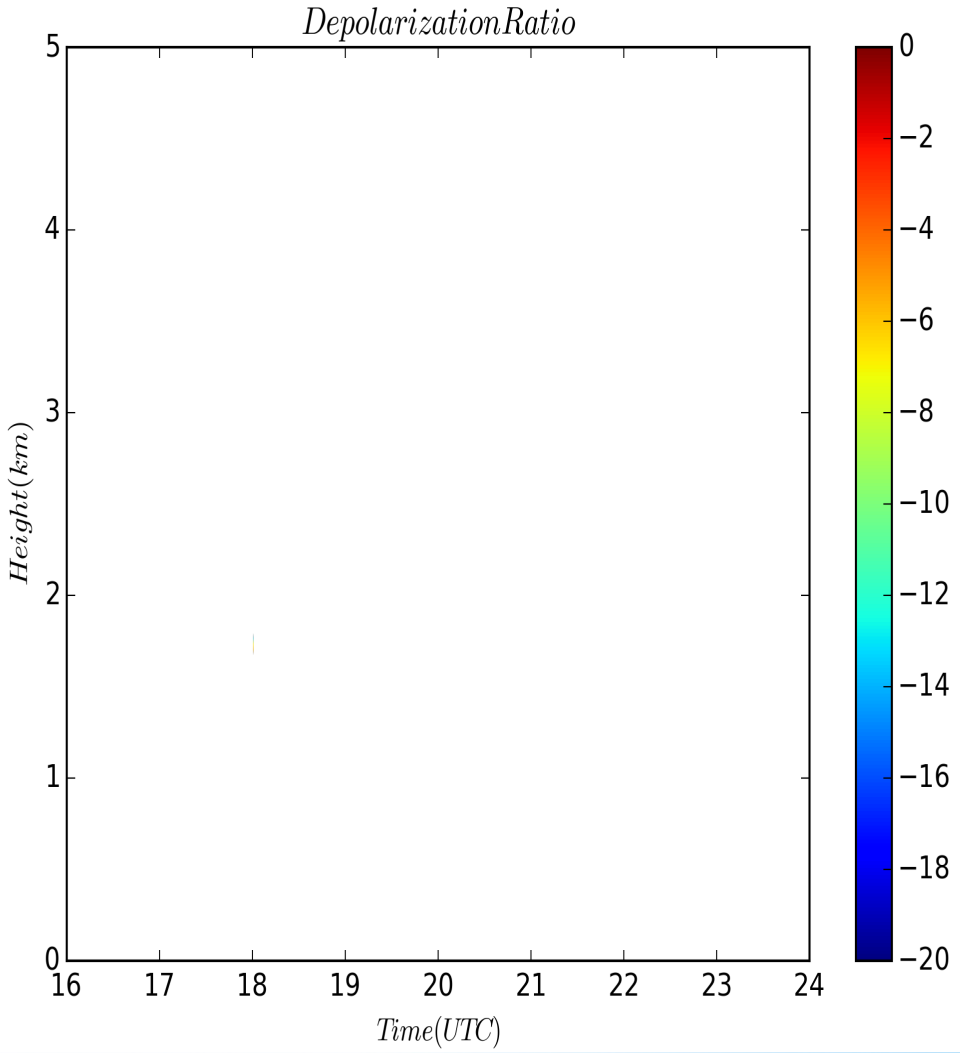
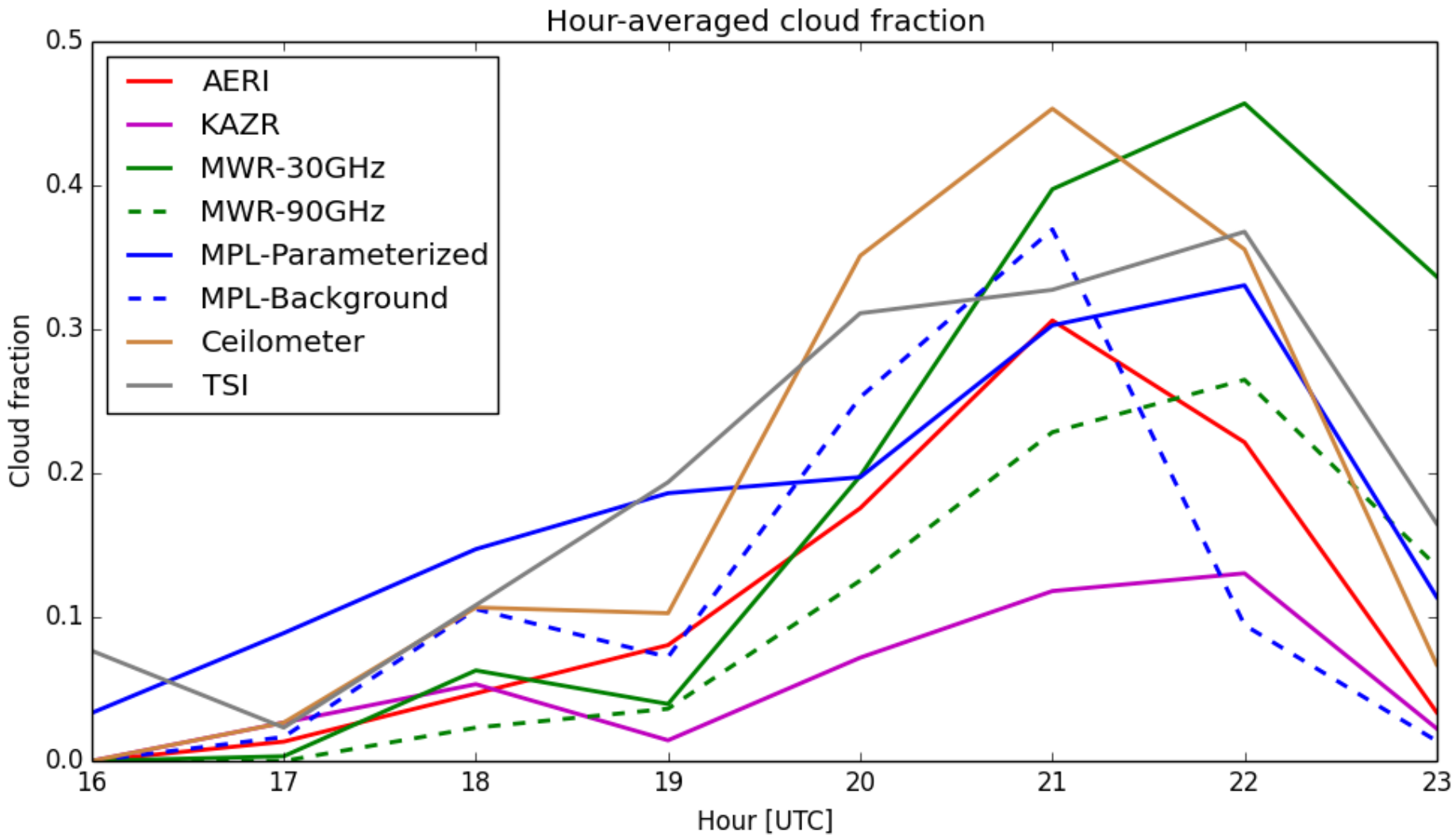


Fig.7b Final real LDR

*Cloud fraction:

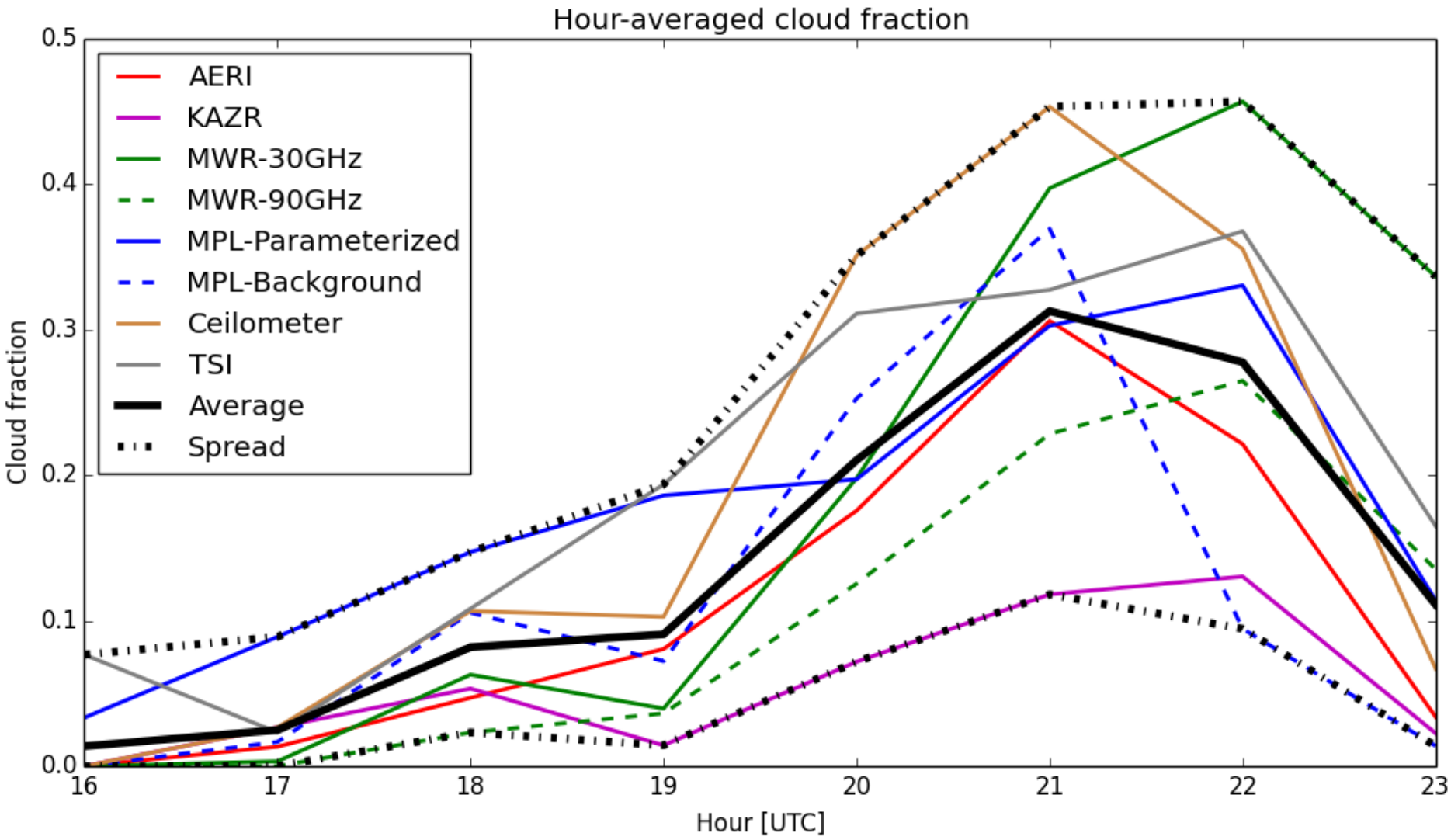


Total (Averaged over 8 hour period) cloud fraction:

AERI	KAZR	MWR-31.4GHz	MWR-90GHz	MPL-Param	MPL-Bkgrd	Ceilometer	TSI
0.1097	0.0547	0.1109	0.1017	0.1750	0.1156	0.1829	0.1967

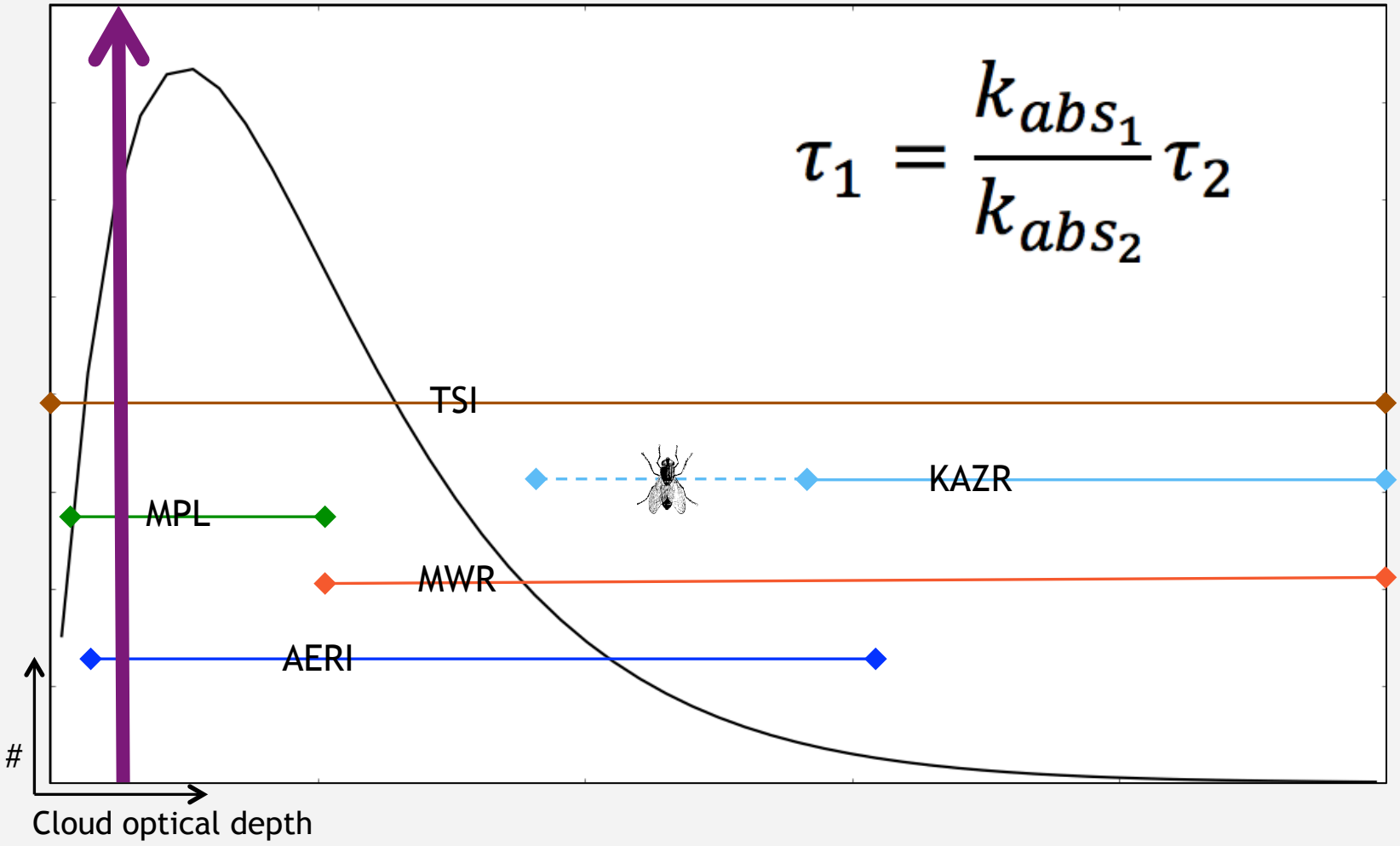
*Conclusions:

Uncertainty?



To be continued…

What is a cloud?



So, what is a cloud?

H

It depends on the application!