COMPARISON OF FM-CW AND PULSED CLOUD RADARS AND LIDAR PERFORMANCE

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1. VERTICALLY POINTING CLOUD RADAR (35 and 94GHz)

All weather performance?

Calibration?

FM versus Pulsed Radar.

2. VERTICALLY POINTING LIDAR

All weather performance.

Calibration.

Separation molecular and Mie at 355nm

Will the models assimilate dBZ and β, or derived quantities such as LWC, IWC….??

In any case error estimates are crucial

VERTICALLY POINTING CLOUD RADAR

All weather performance: 35 &94GHz (8.6&3.2mm)

- At 94GHz rain on the antenna: 9-14dB loss of signal.
- Precise value impossible to estimate.
- Need a rapid response rain sensor to flag this and reject data when there may be water on the antenna
- Solution? Use an X-band (3cm) radar in the rain. No attenuation, lower sensitivity, but raining clouds will have high Z.

Calibration.

- Link budget (Hardware calculation) only good to a few dB!
- Compare with another calibrated radar!
- At 94GHz in rain (3-10mm/hr) combined attenuation and Mie scattering gives a Z of 19dBZ (± 1dB) at 250m range (tip radar off-vertical and shelter the antenna from the rain)
- Not clear what to do at 35GHz???

REF: Hogan, Illingworth et al J Tech: 20, 572-280 (2003)

Frequency Modulated Continuous Wave or Pulsed Radar.

Advantages of FM/CW.

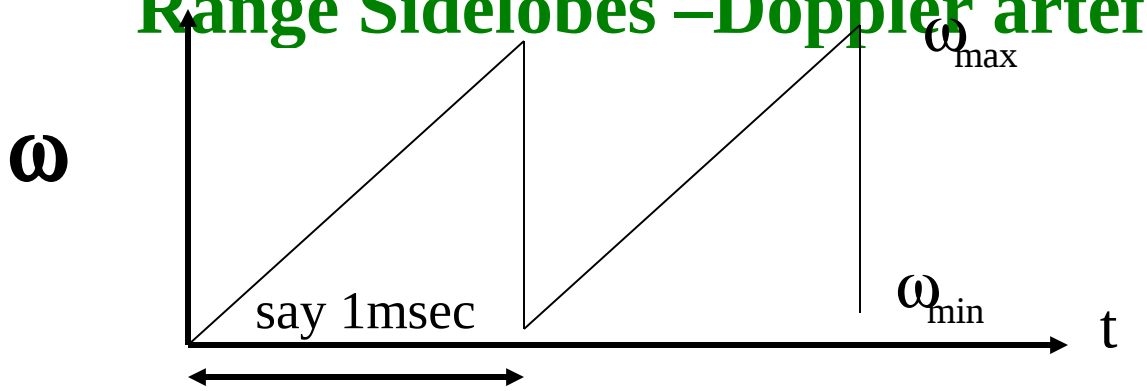
Much lower peak power.

Cheaper and more reliable.

Longer lifetime of transmitter.

Disadvantages of FM/CW.

Range Sidelobes –Doppler artefacts.



Fourier Analysis of received power: frequency gives range.

BUT: 1. Big vertical gradient in Z - big increase in return signal, spread of frequencies – spread of echo to neighbouring gates.

2. Doppler shift of return will look like a change in range.

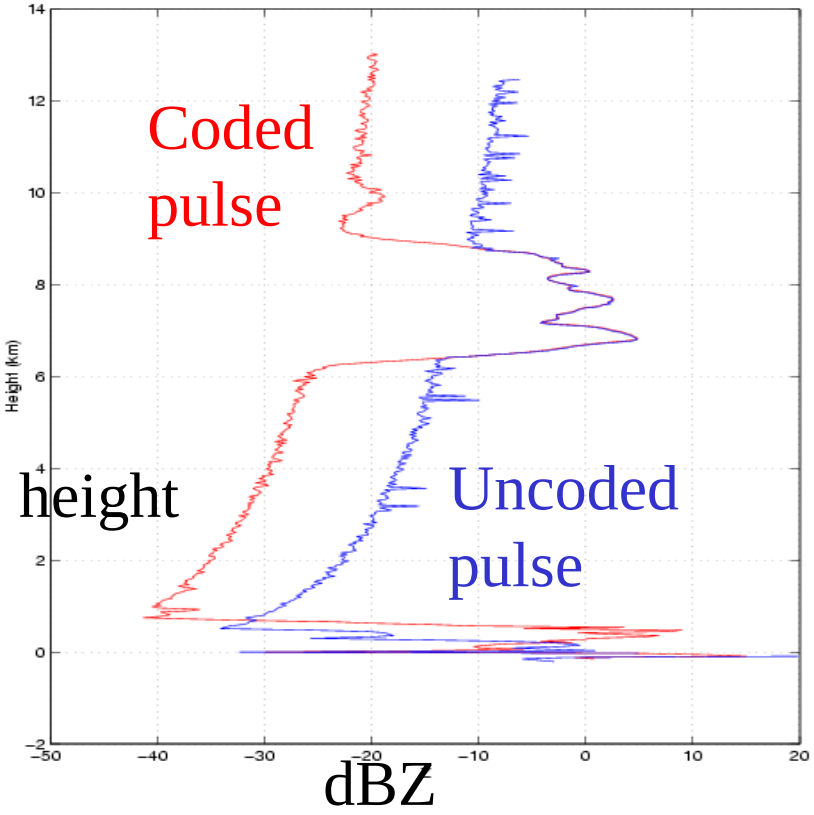
Chilbolton example compare 35GHz radar:

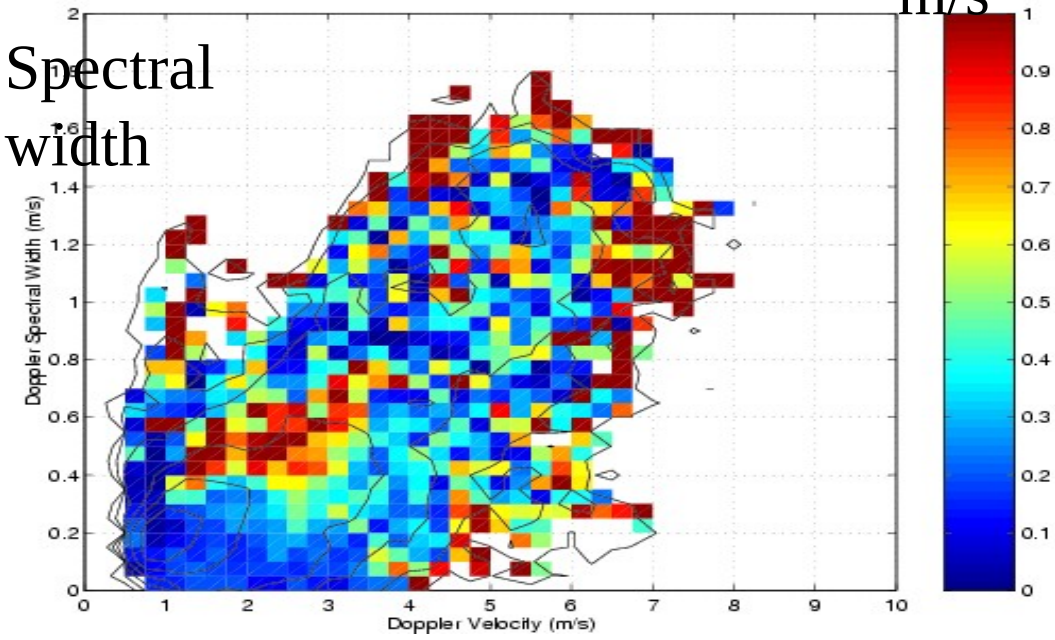
Pulse mode with

14 bit random binary pulse code should give 10dB extra gain.

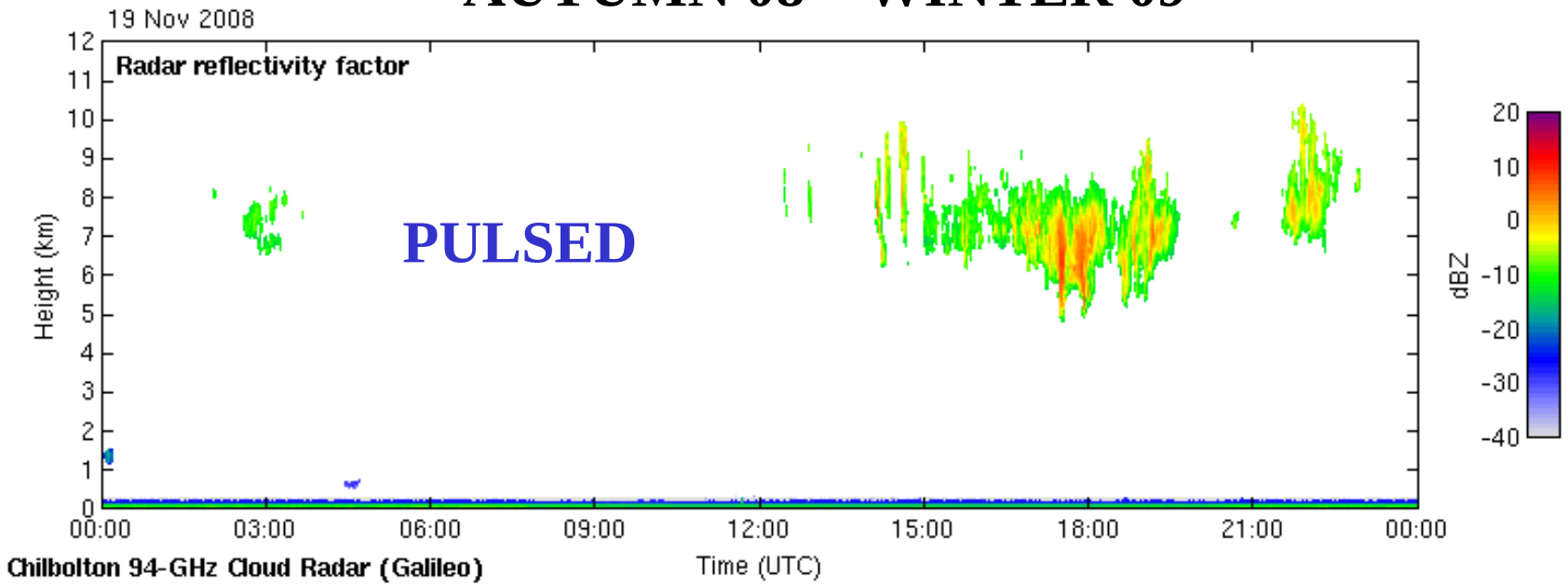
Red line shows 10dB extra gain.
30dB increase in echo at 6km
and NO SIDE LOBES.

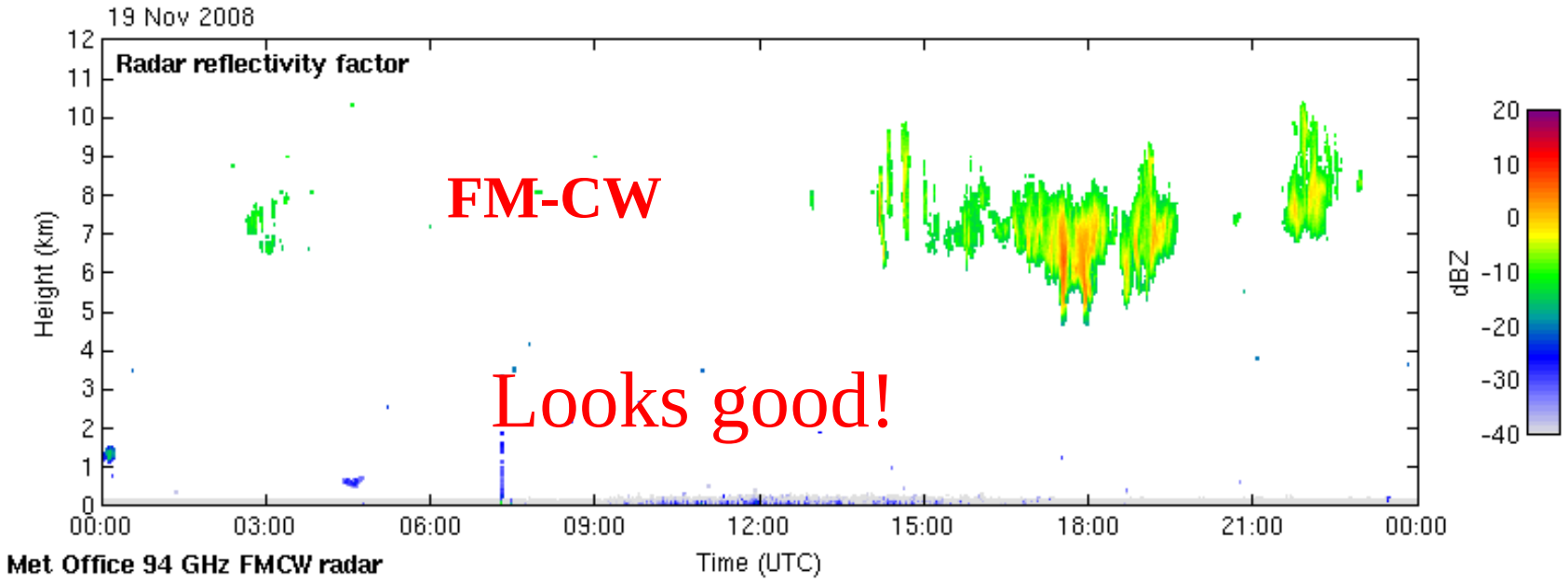
BUT Doppler is compromised: by up to 1m/s if the target has a spectral width.

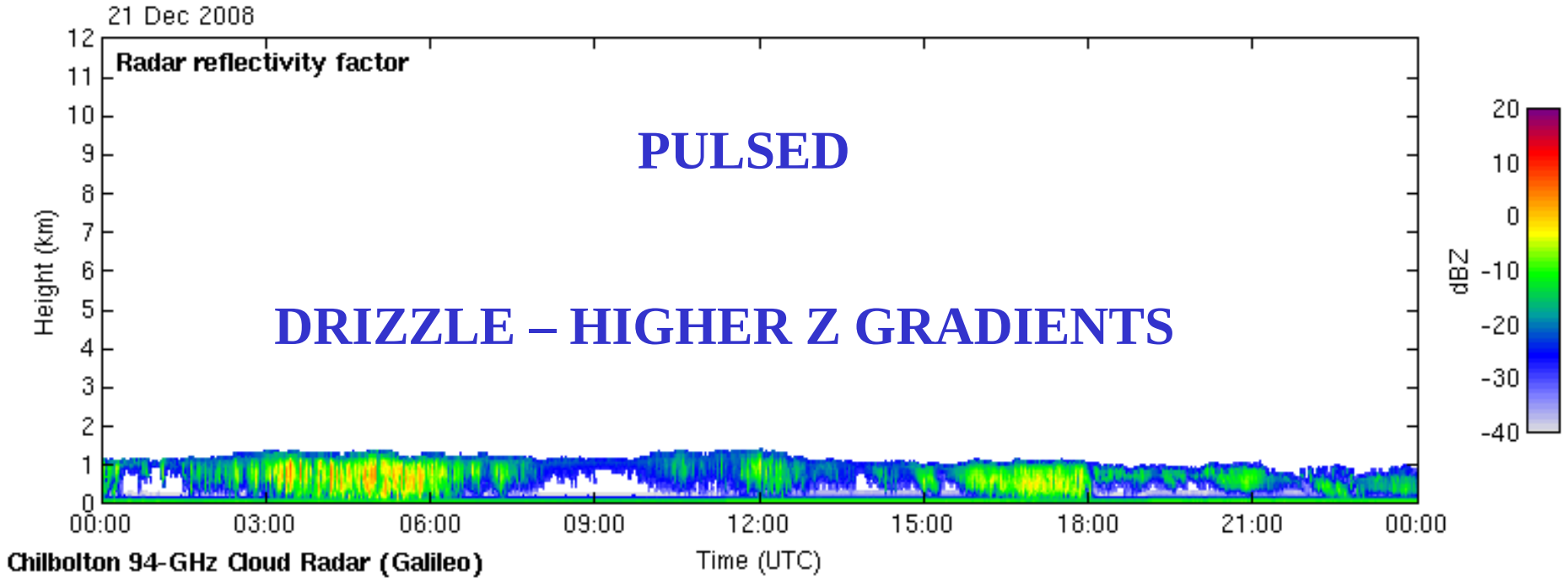


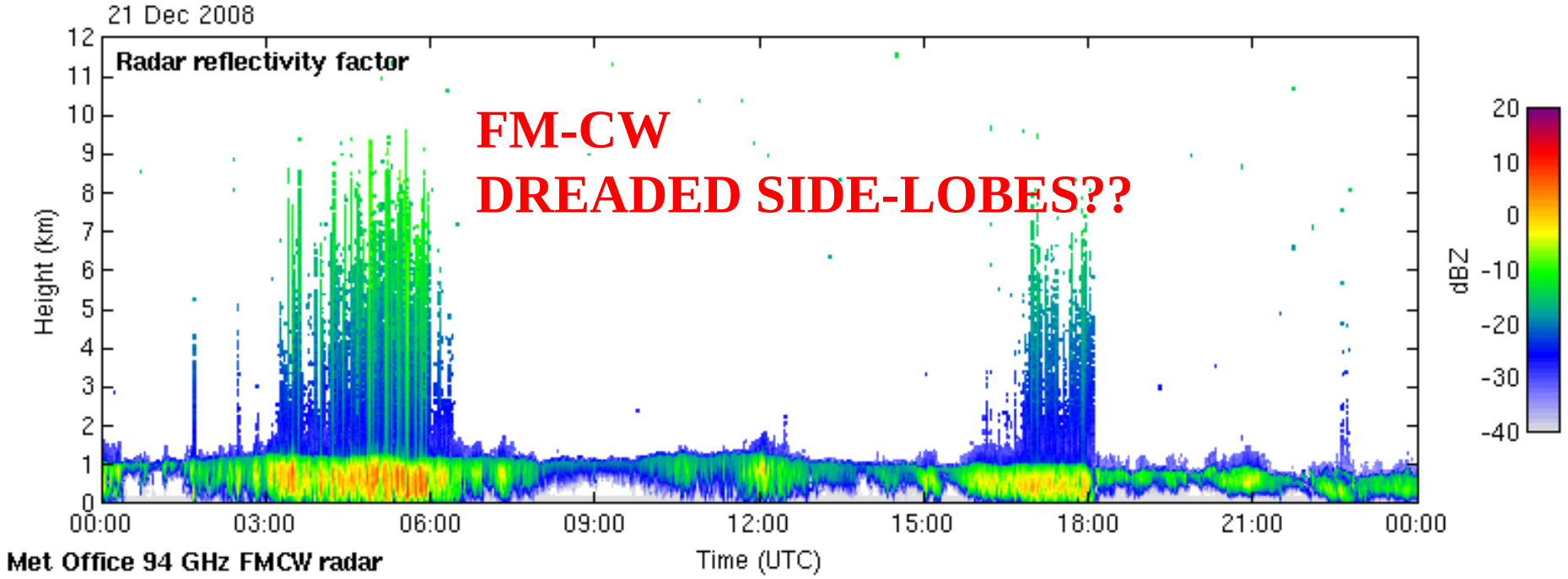


COMPARISONS OF 94GHz PULSED VERSUS FM-CW: AUTUMN 08 – WINTER 09

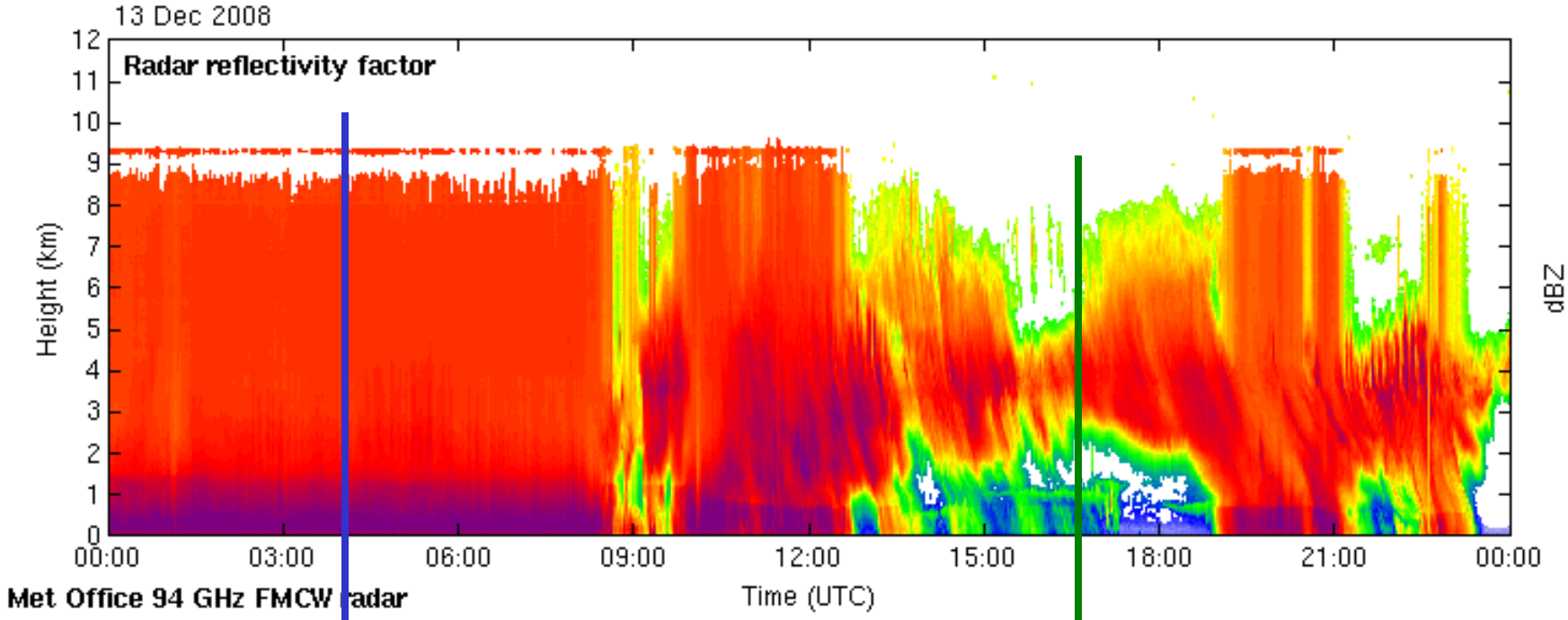


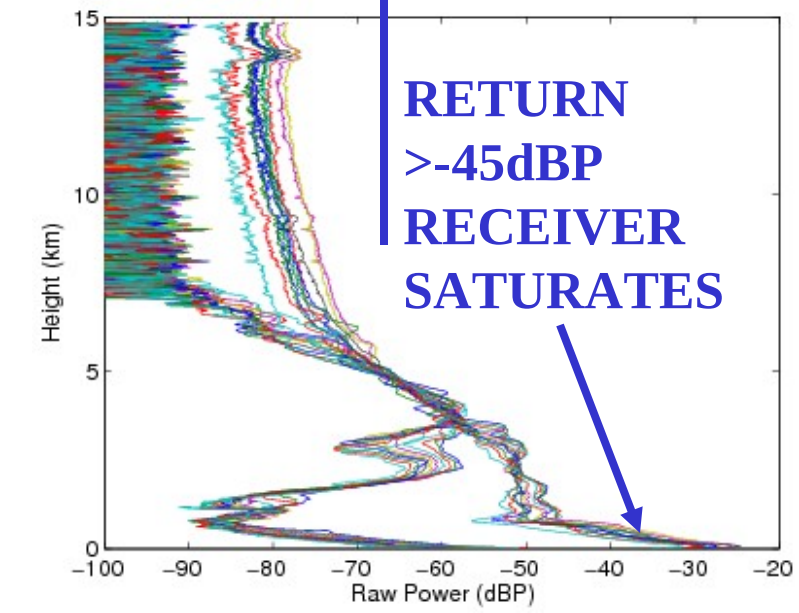



21 Dec 2008
Radar reflectivity factor
PULSED
DRIZZLE – HIGHER Z GRADIENTS
Height (km)
dBZ
Time (UTC)
Chilbolton 94-GHz Cloud Radar (Galileo)

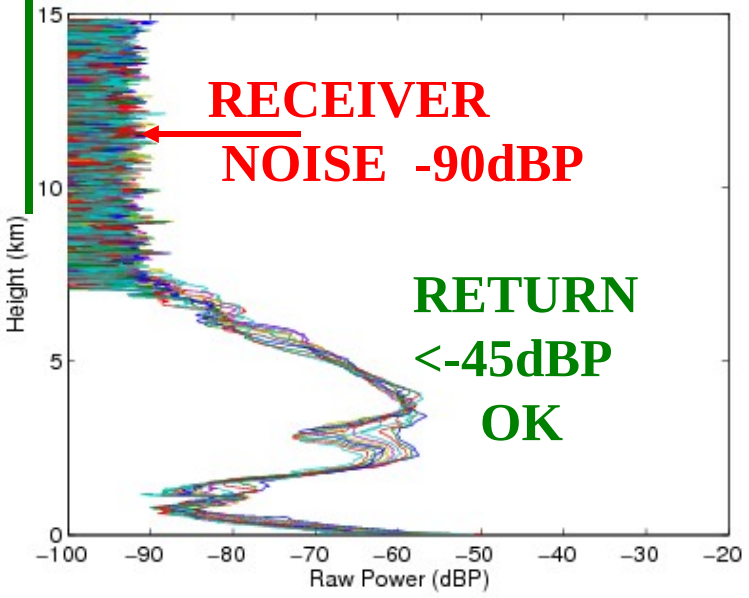

21 Dec 2008
Radar reflectivity factor
FM-CW
DREADED SIDE-LOBES??
Height (km)
dBZ
Time (UTC)
Met Office 94 GHz FMCW radar

FM-CW IN RAIN: NOT SIDELOBES BUT RECEIVER SATURATION





PLOTS OF RETURN POWER AGAINST HEIGHT



RADAR CONCLUSIONS:

1..Calibration still a problem.

2. X-band for all weather?

3. FM/CW can have (solvable) problem with receiver saturation

4. Modern coding techniques can reduce Z sidelobes to a dB or so and Doppler to <1m/s.

4. This is usually acceptable if Z is used to estimate ice water content and V for general terminal velocities.

HOWEVER SUCH ARTEFACTS MEAN THAT

DON'T USE FM/CW FOR DUAL WAVELENGHT SUDIES.

{FOR THESE YOU NEED ΔZ to < 0.1dB and ΔV to < 0.1m/s}

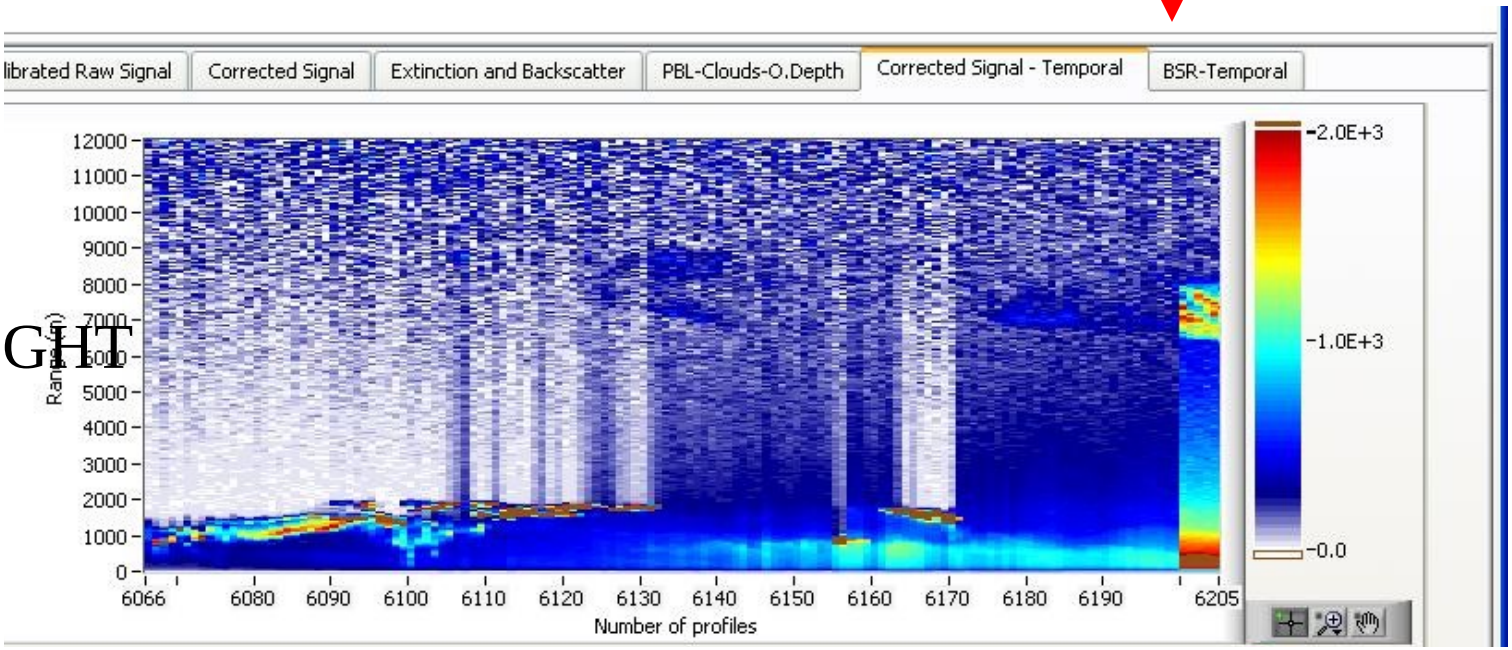
LIDAR:

1. All weather performance
2. Calibration
3. Signal processing at 355nm – separate molecular from Mie

What is the effect of rain on the window?

Clear the window and what is the difference?

CLEAN GLASS HERE



HEIGHT

TIME

LIDAR: All weather performance

Need to install way of keeping the window dry.

Many lidars have recessed window and already blow warm air.

Do we need to flag large error when it is raining?

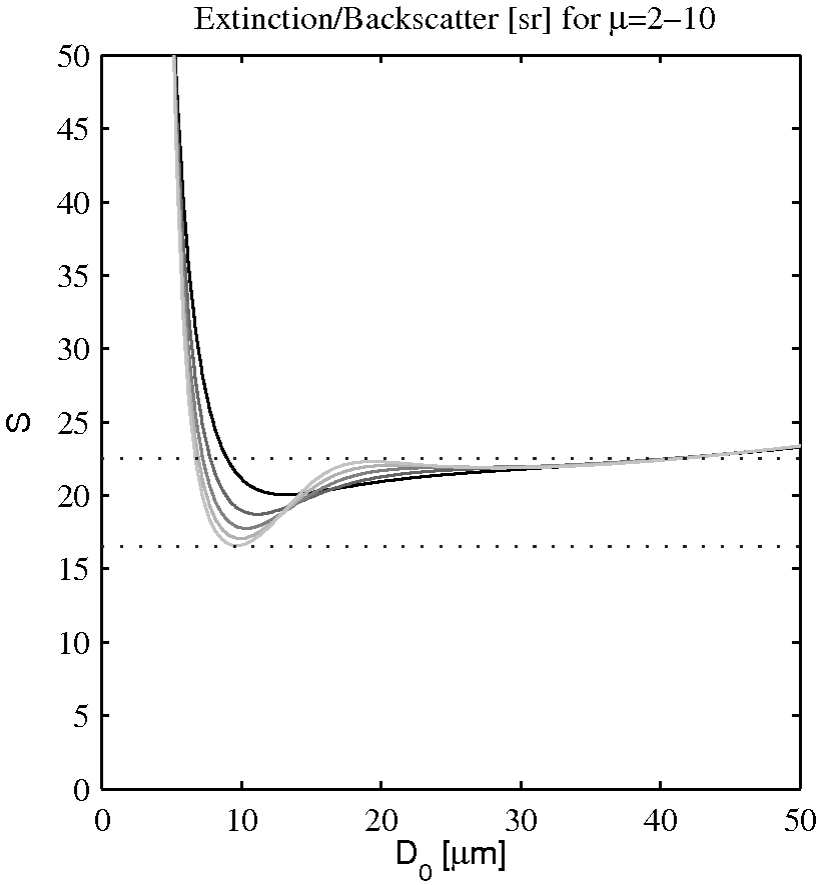
Lidar data not useful anyway when it is raining?

LIDAR: Calibration: 355/532nm use molecular return.
Longer wavelengths – Calculate the integrated backscatter, $\int \beta_{obs}\, dz$,
through water cloud which extinguishes the lidar beam.

$\int \beta_{obs}\, dz = 1/2S$, where S is the extinction to backscatter ratio.

For water clouds such as stratocumulus $S \approx 20$.

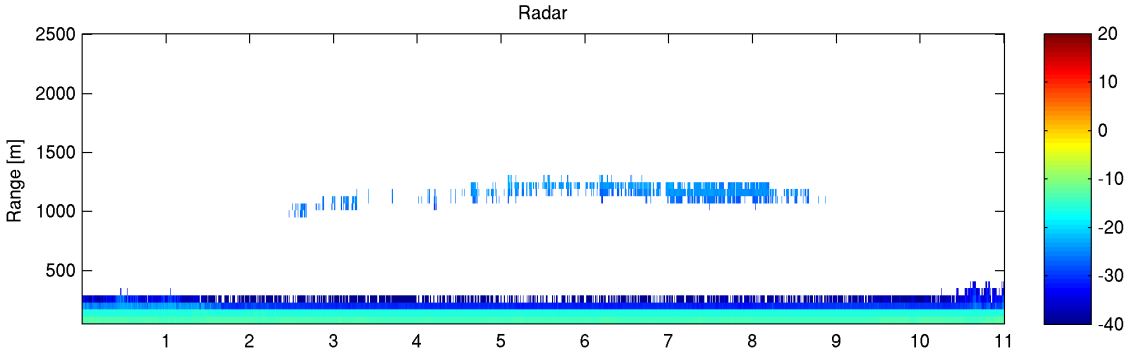
{O'Connor et al J Tech 2004, 21, 777-786}



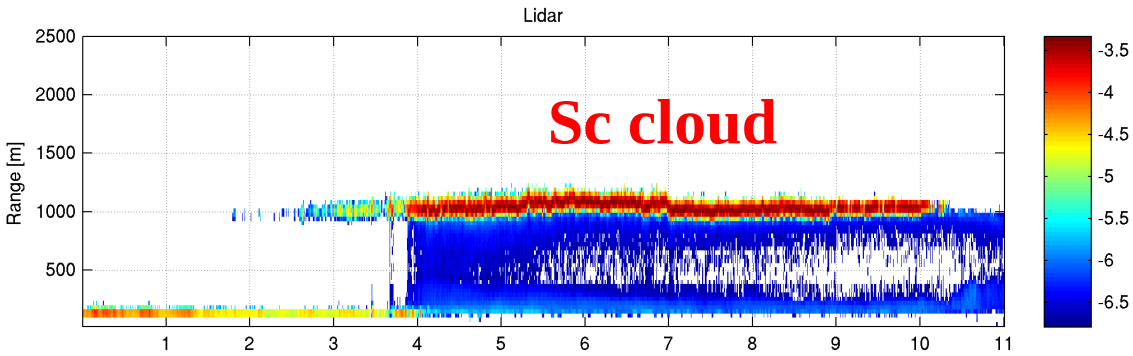
S is approx constant for stratocumulus

S insensitive to changes in volume mode diameter.

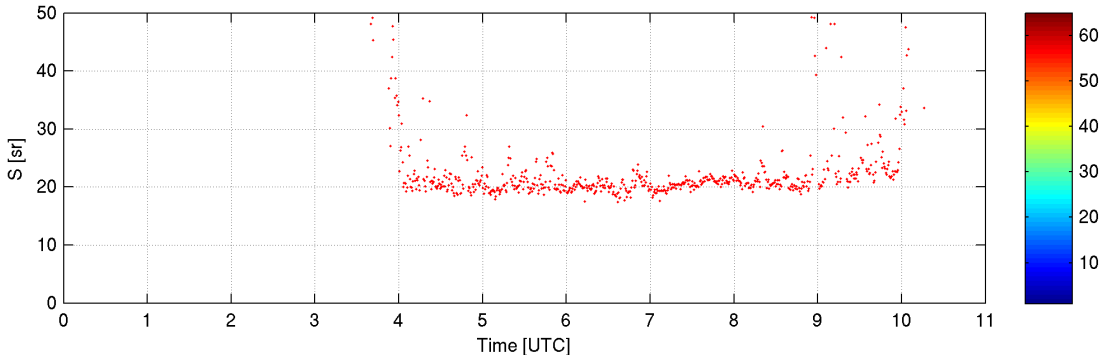
EXAMPLE OF CALIBRATION OF 1.5μm HALO LIDAR (field of view 6μrad – no multiple scattering problems)



RADAR



LIDAR

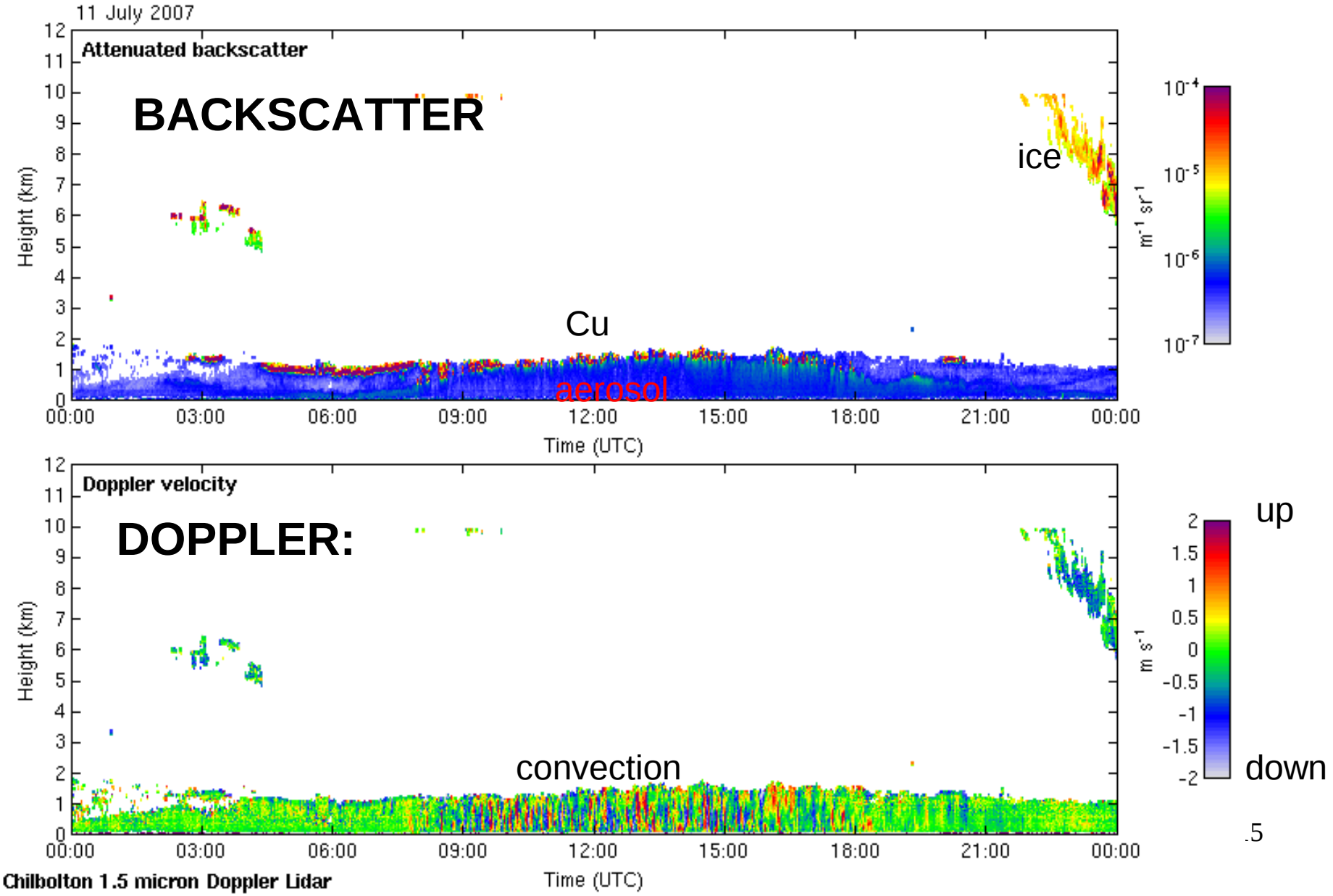


ADJUST β_{obs} CALIBATION UNTIL

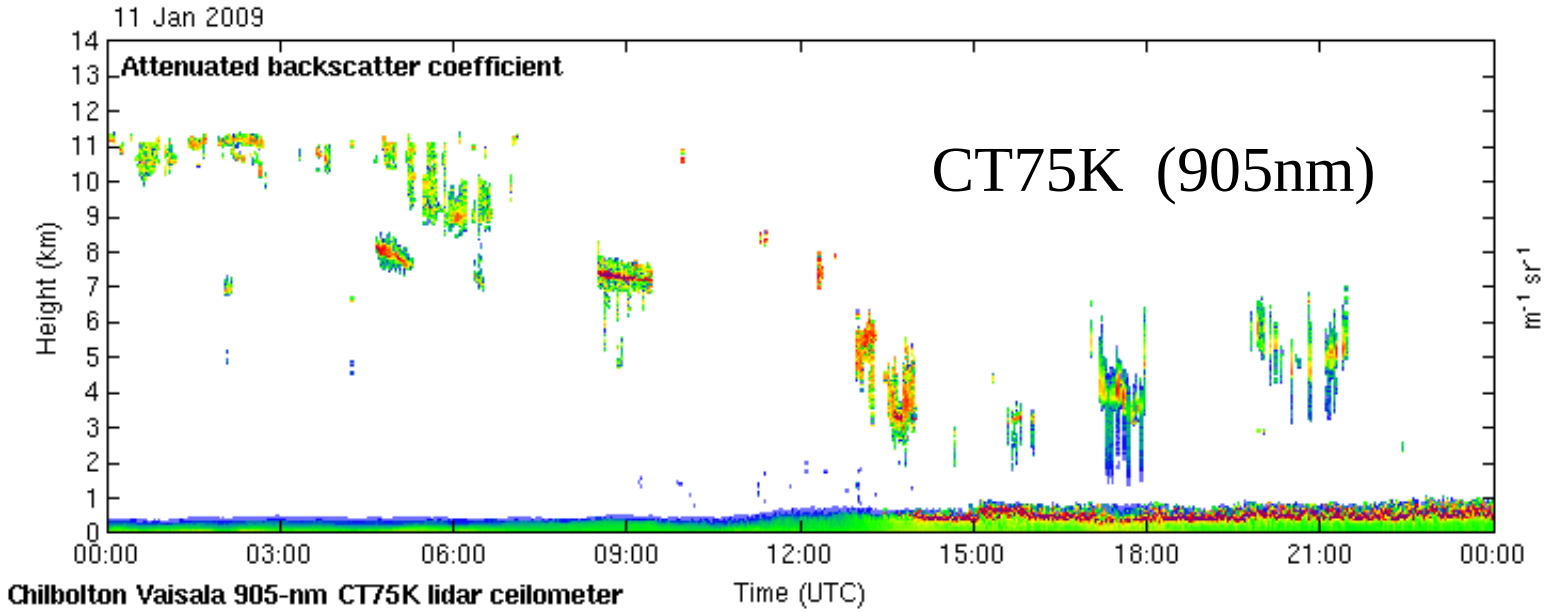
$\int \beta_{obs}\, dz = 1/2S.$

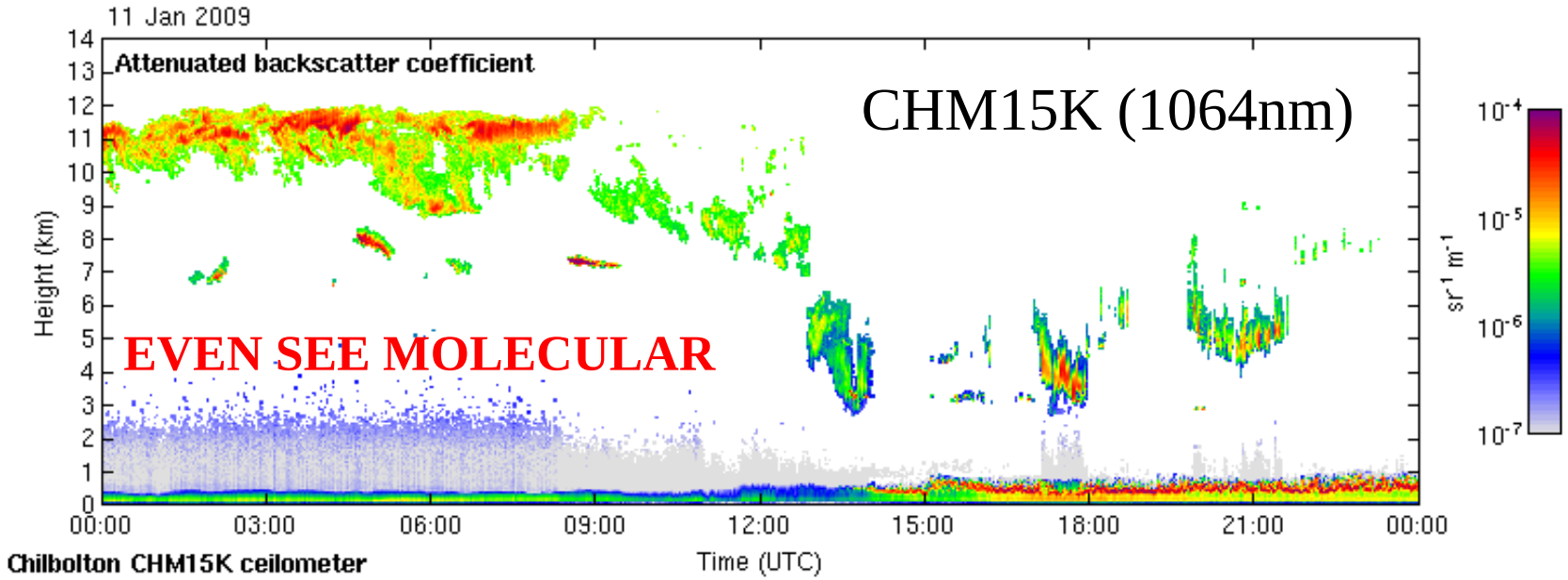
HALO: 1.55μm **Doppler** Lidar – aerosol & clouds: 11 Jul 2007:

V good for studying air flow in the boundary layer!

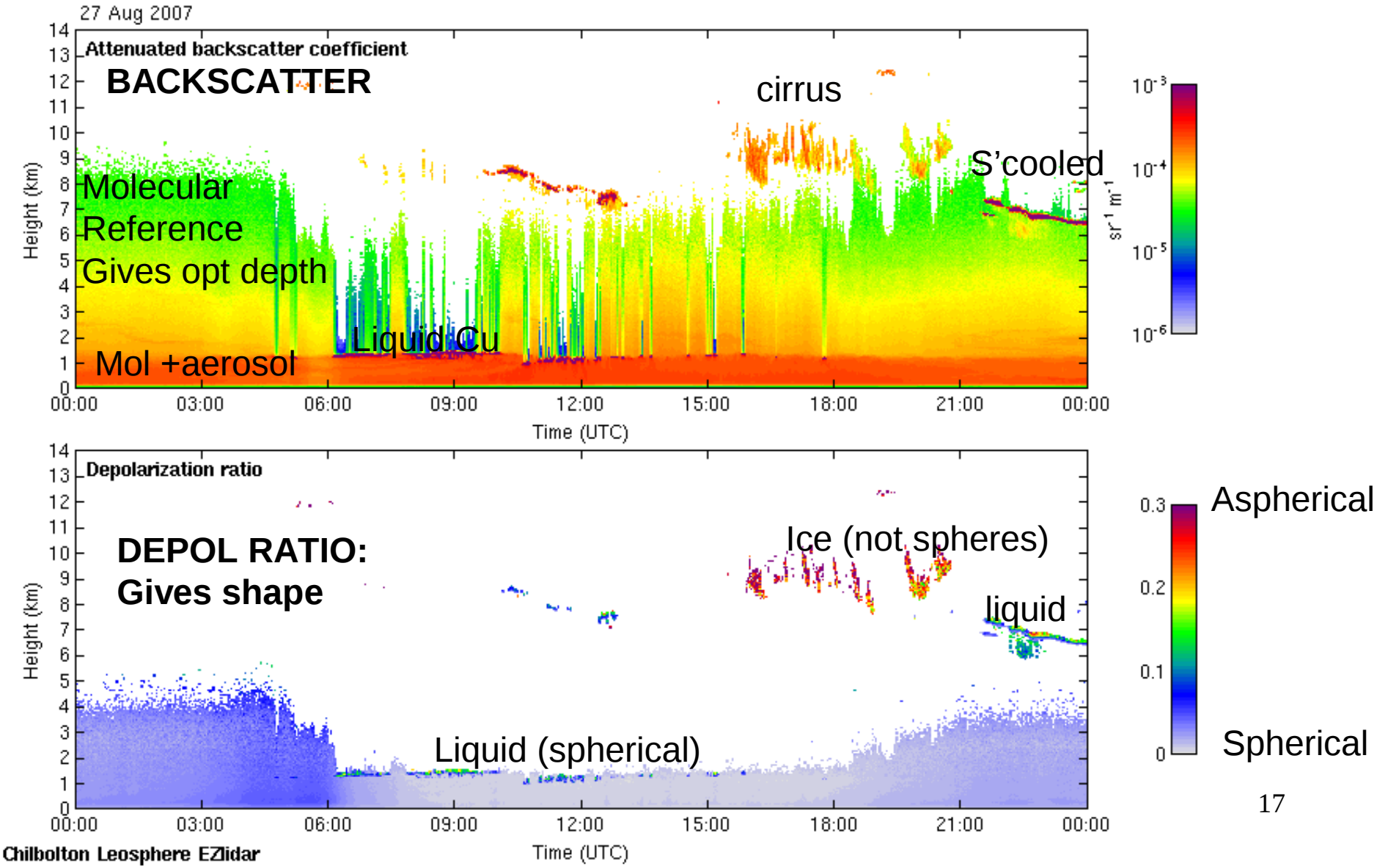


COMPARISON OF CEILOMETERS AT CHILBOLTON





UV EZY 355nm Lidar: Need to implement method to separate the molecular return from aerosols and clouds



UESTIONS FOR WG1:

Radar

Need rain/dampness sensor. (same needed for radiometers?)

X-band for all weather? Sensitivity OK?

FM/CW level of range side lobes – are they acceptable? (STSM?)

Care if using dual wavelength ratio for lwc, ice particle size…..

Lidar

Calibration - can use integrated backscatter.

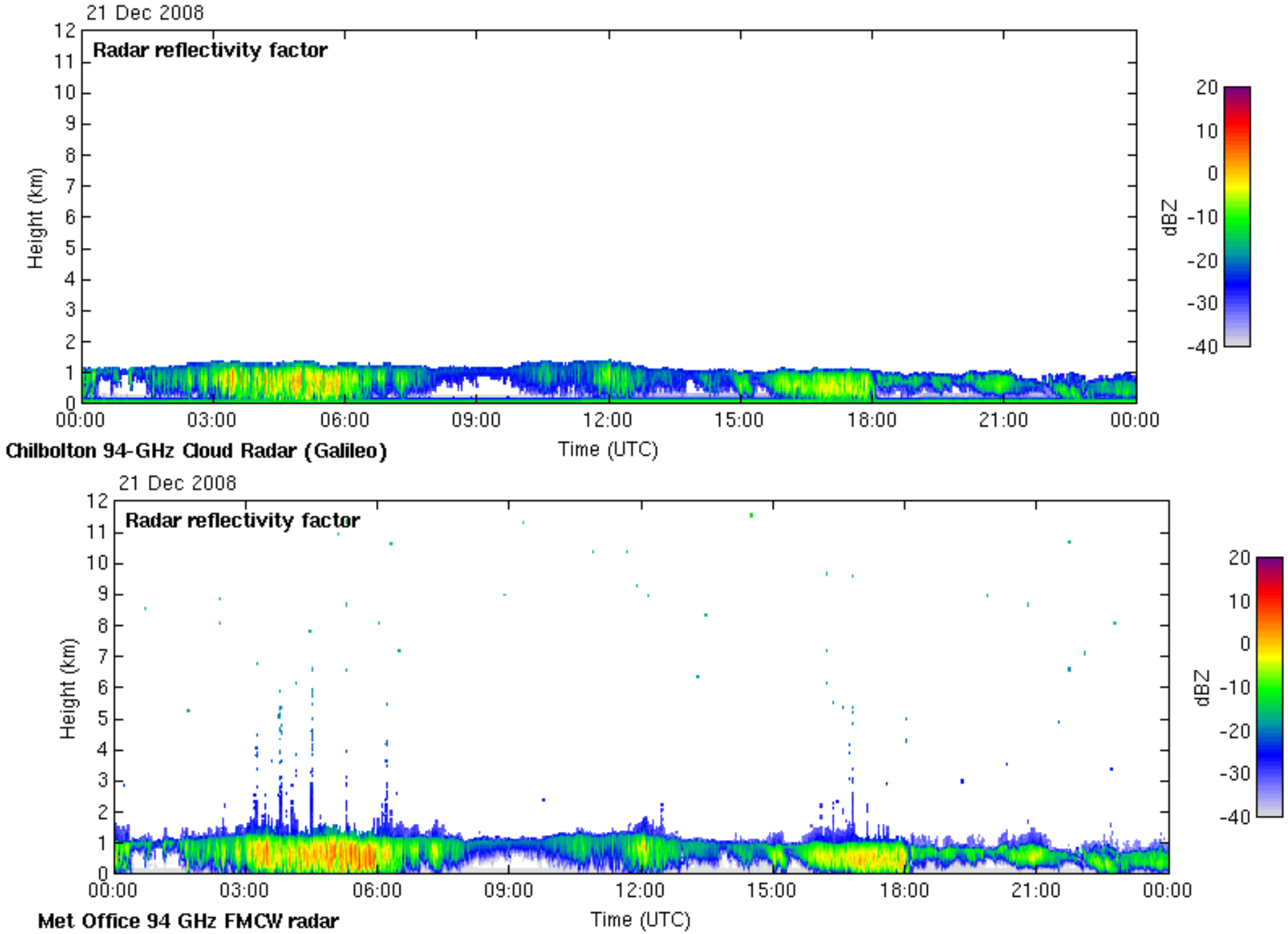
- may need to correct for multiple scattering.

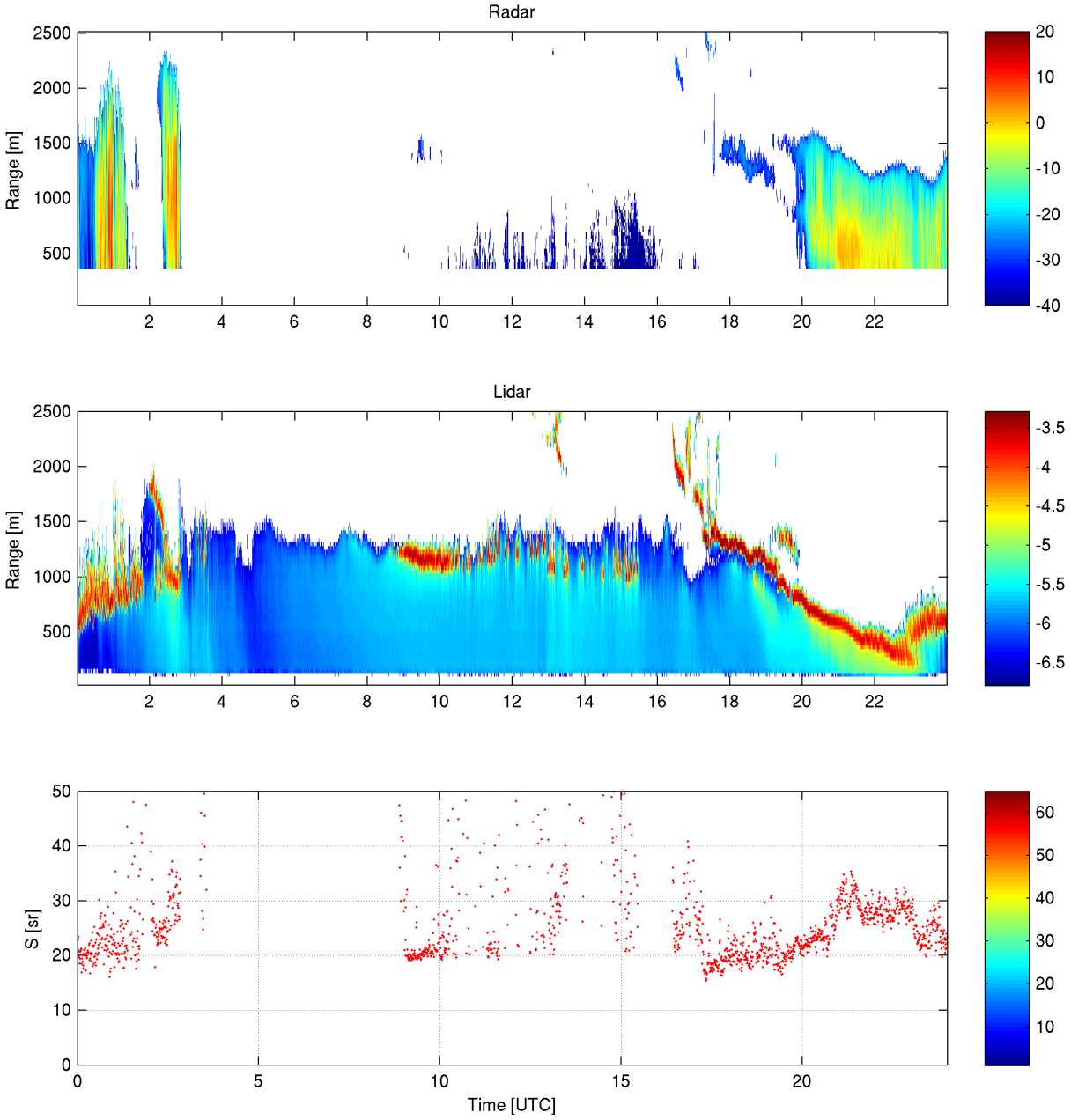
Infer drop size/concentration from two lidars with different field of view and so different multiple scattering? (STSM?)

355nm lidar – how best to separate molecular return and Mie return om aerosols and clouds. Optimisation approach? (STSM?)
Molecular return gives direct observation of optical depth).
al solution: high spectral resolution lidar – expensive?

RAMAN – all weather, unattended?

In all cases need errors if data to be assimilated.


21 Dec 2008
Radar reflectivity factor
Height (km)
0
1
2
3
4
5
6
7
8
9
10
11
12
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
Time (UTC)
dBZ
20
10
0
-10
-20
-30
-40
Chilbolton 94-GHz Cloud Radar (Galileo)
21 Dec 2008
Radar reflectivity factor
Height (km)
Time (UTC)
dBZ
Met Office 94 GHz FMCW radar


Radar
Range [m]
2500
2000
1500
1000
500
2
4
6
8
10
12
14
16
18
20
22
20
10
0
-10
-20
-30
-40
Lidar
Range [m]
2500
2000
1500
1000
500
2
4
6
8
10
12
14
16
18
20
22
-3.5
-4
-4.5
-5
-5.5
-6
-6.5
S [sr]
50
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Time [UTC]
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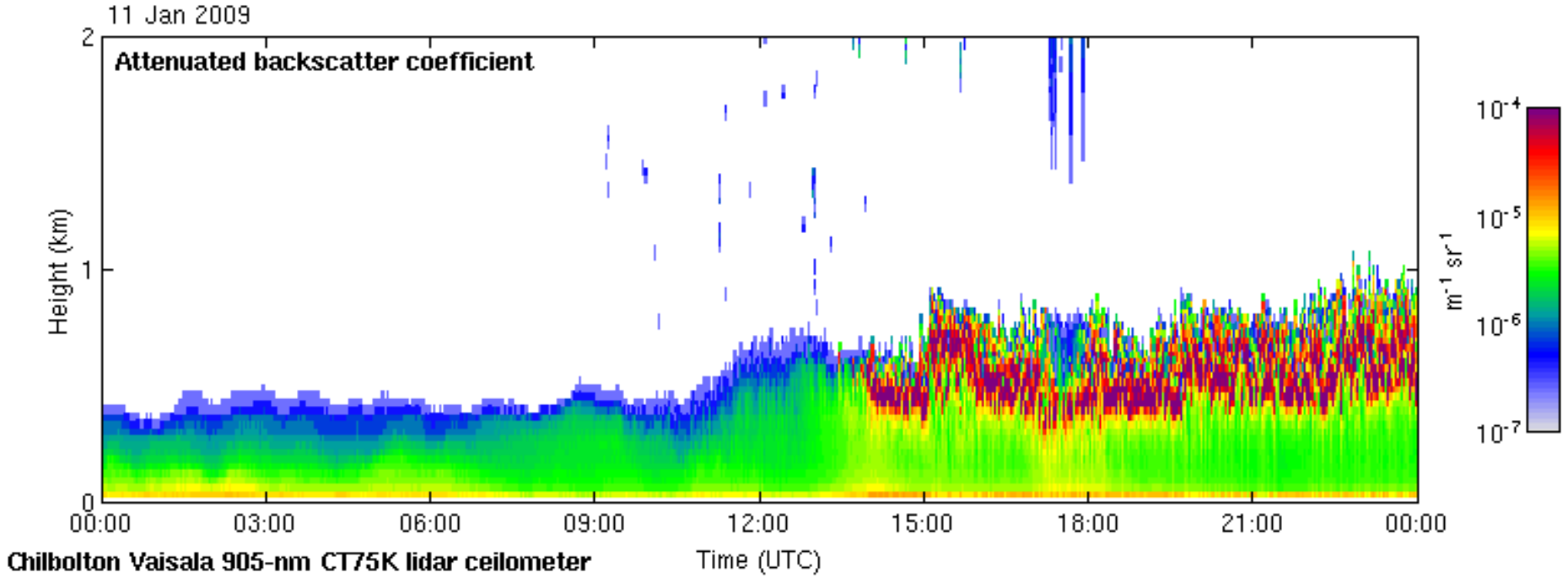
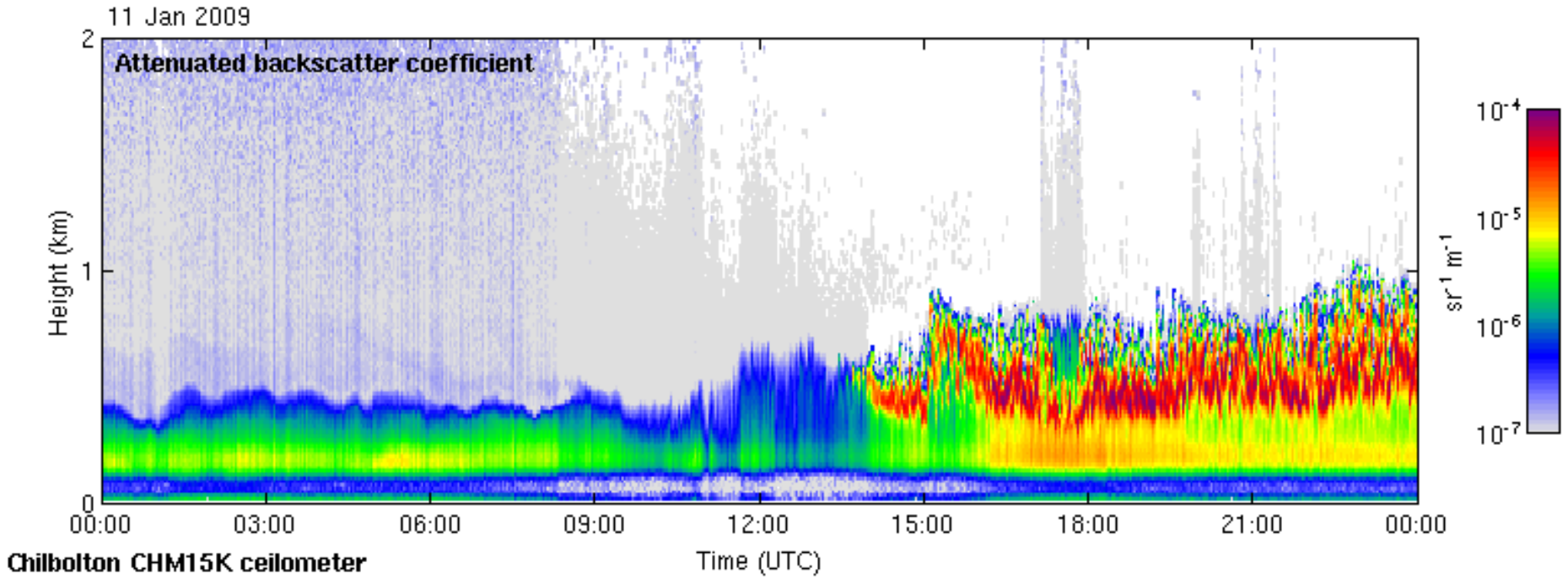
10



Chilbolton Vaisala 905-nm CT75K lidar ceilometer



Chilbolton CHM15K ceilometer