# Unusual cloud. An Investigation.
## 19th October 2018.

**Bernard Burton. Wokingham.**

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# Unusual Cloud – an Investigation

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Fig 1

Fig 2

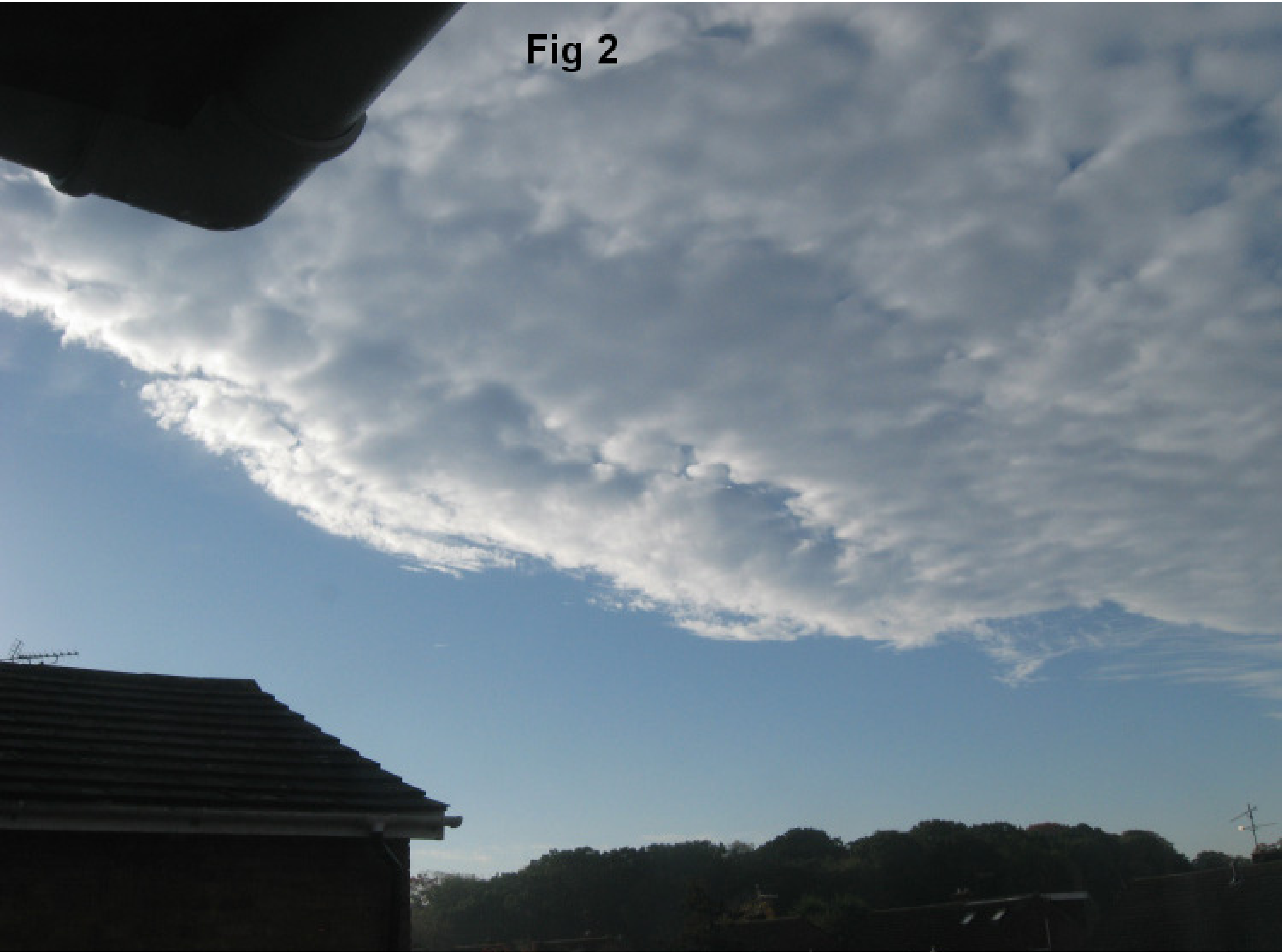


Fig 3

Fig 4

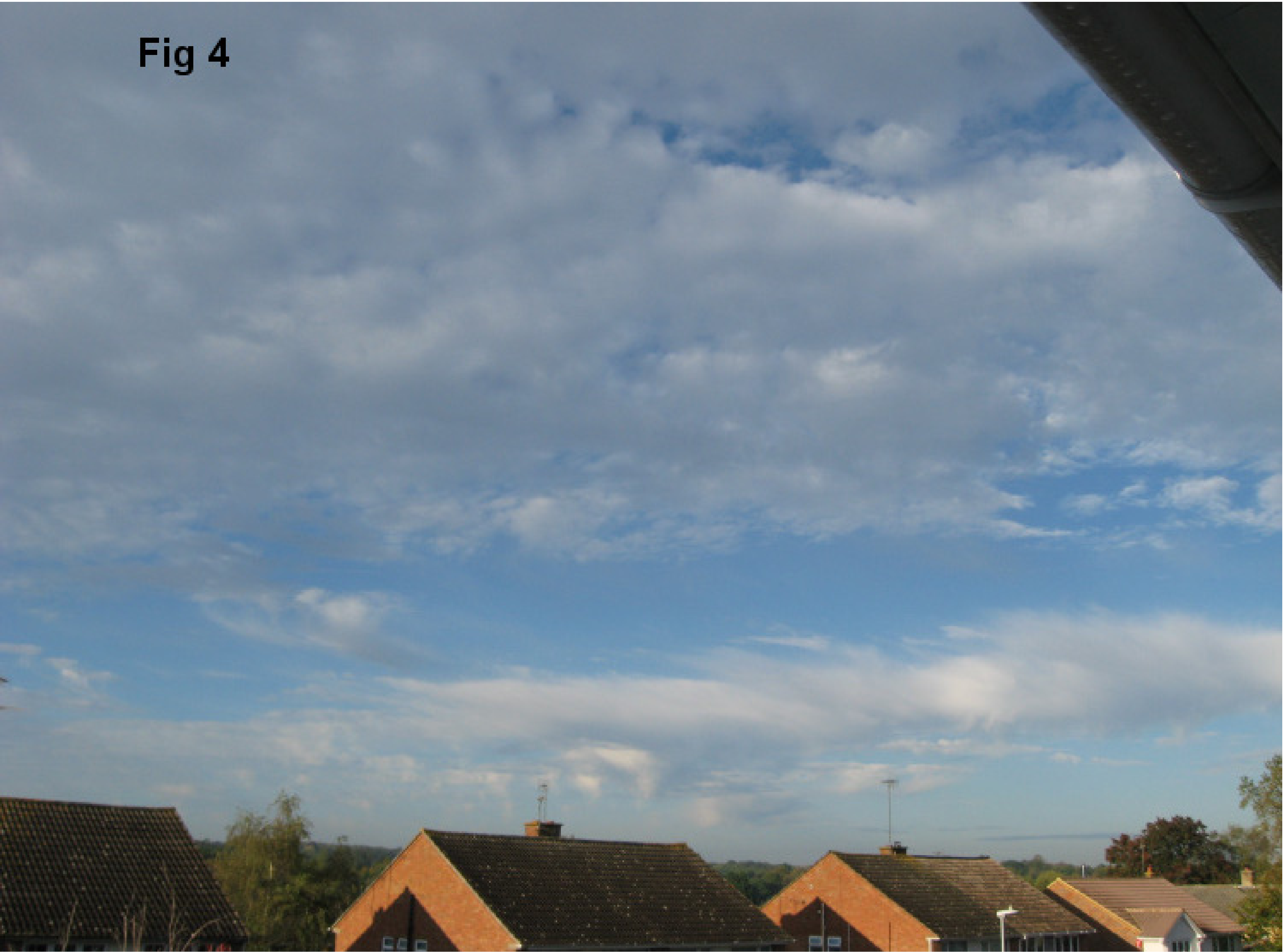


Fig 5

Fig 6

Fig 7

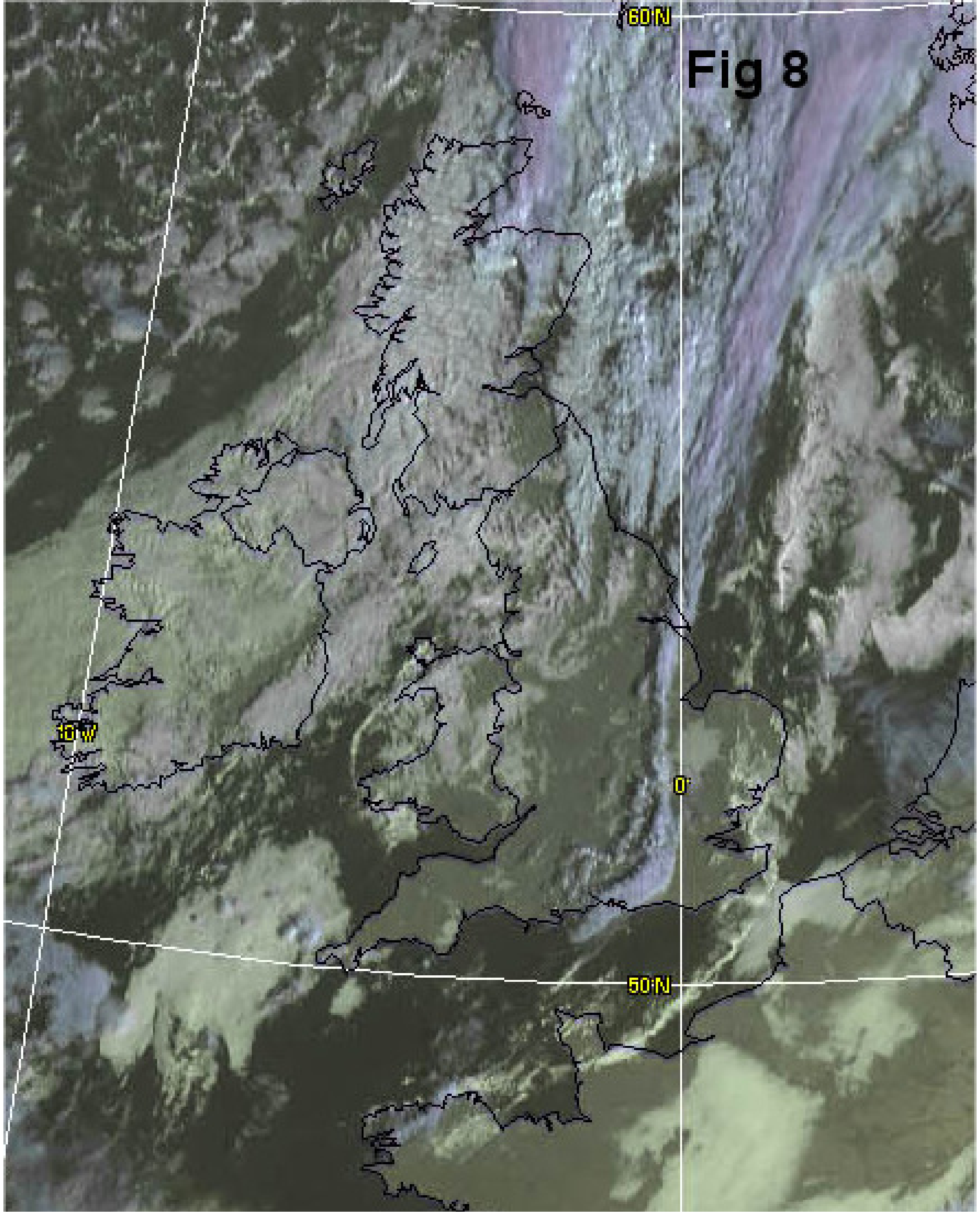
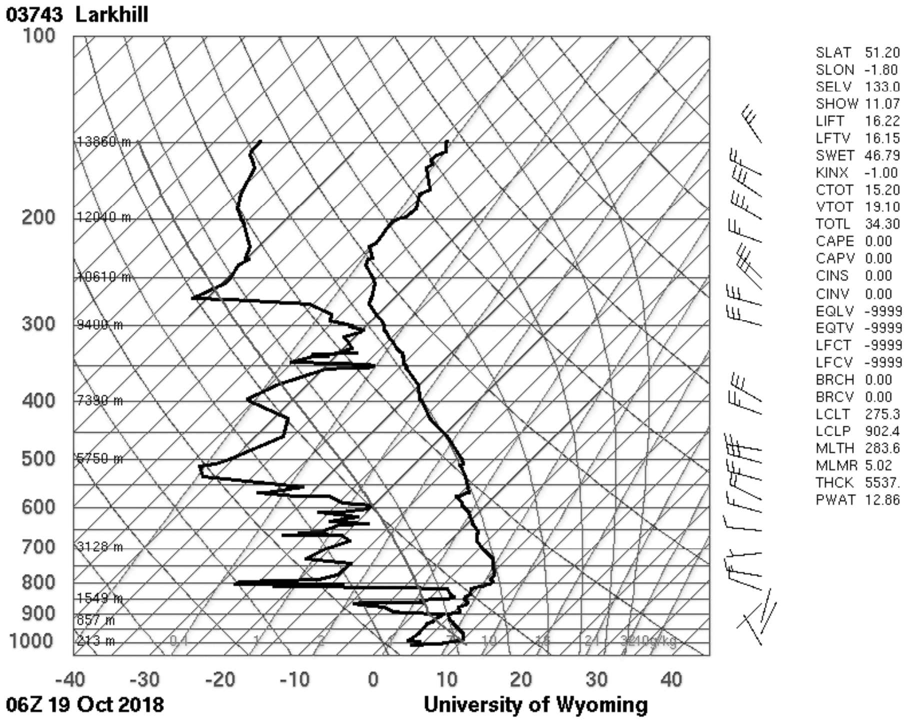


Fig 8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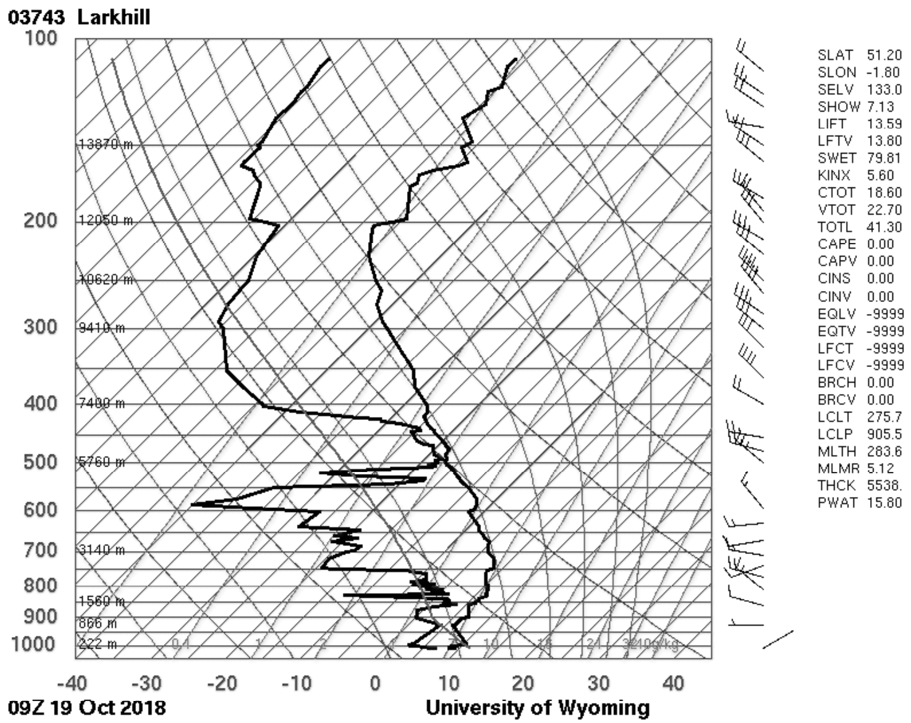
SLAT 51.20
SLON -1.80
SELV 133.0
SHOW 11.07
LIFT 16.22
LFTV 16.15
SWET 46.79
KINX -1.00
CTOT 15.20
VTOT 19.10
TOTL 34.30
CAPE 0.00
CAPV 0.00
CINS 0.00
CINV 0.00
EQLV -9999
EQTV -9999
LFCT -9999
LFCV -9999
BRCH 0.00
BRCV 0.00
LCLT 275.3
LCLP 902.4
MLTH 283.6
MLMR 5.02
THCK 5537.
PWAT 12.86
06Z 19 Oct 2018
University of Wyoming


03743 Larkhill
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SLON -1.80
SELV 133.0
SHOW 7.13
LIFT 13.59
LFTV 13.80
SWET 79.81
KINX 5.60
CTOT 18.60
VTOT 22.70
TOTL 41.30
CAPE 0.00
CAPV 0.00
CINS 0.00
CINV 0.00
EQLV -9999
EQTV -9999
LFCT -9999
LFCV -9999
BRCH 0.00
BRCV 0.00
LCLT 275.7
LCLP 905.5
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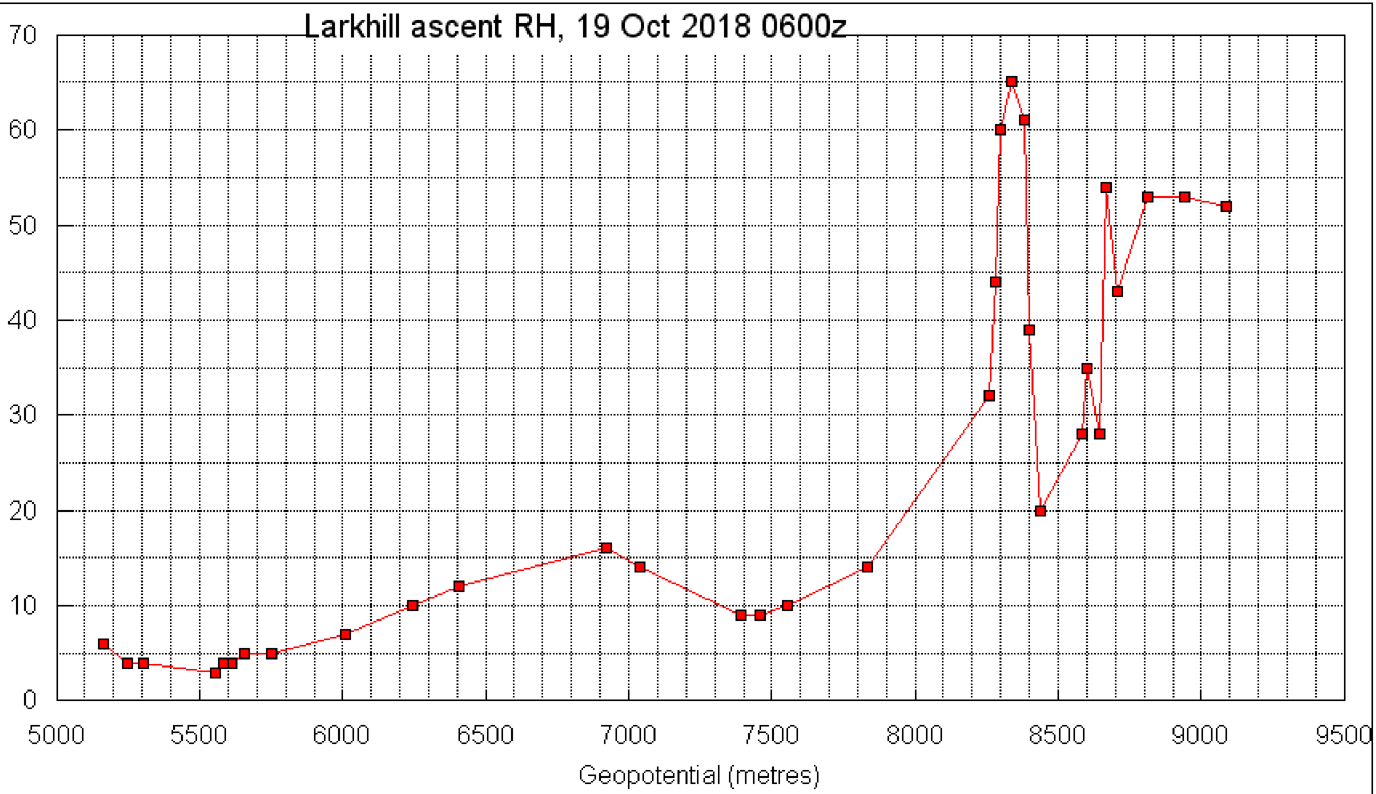
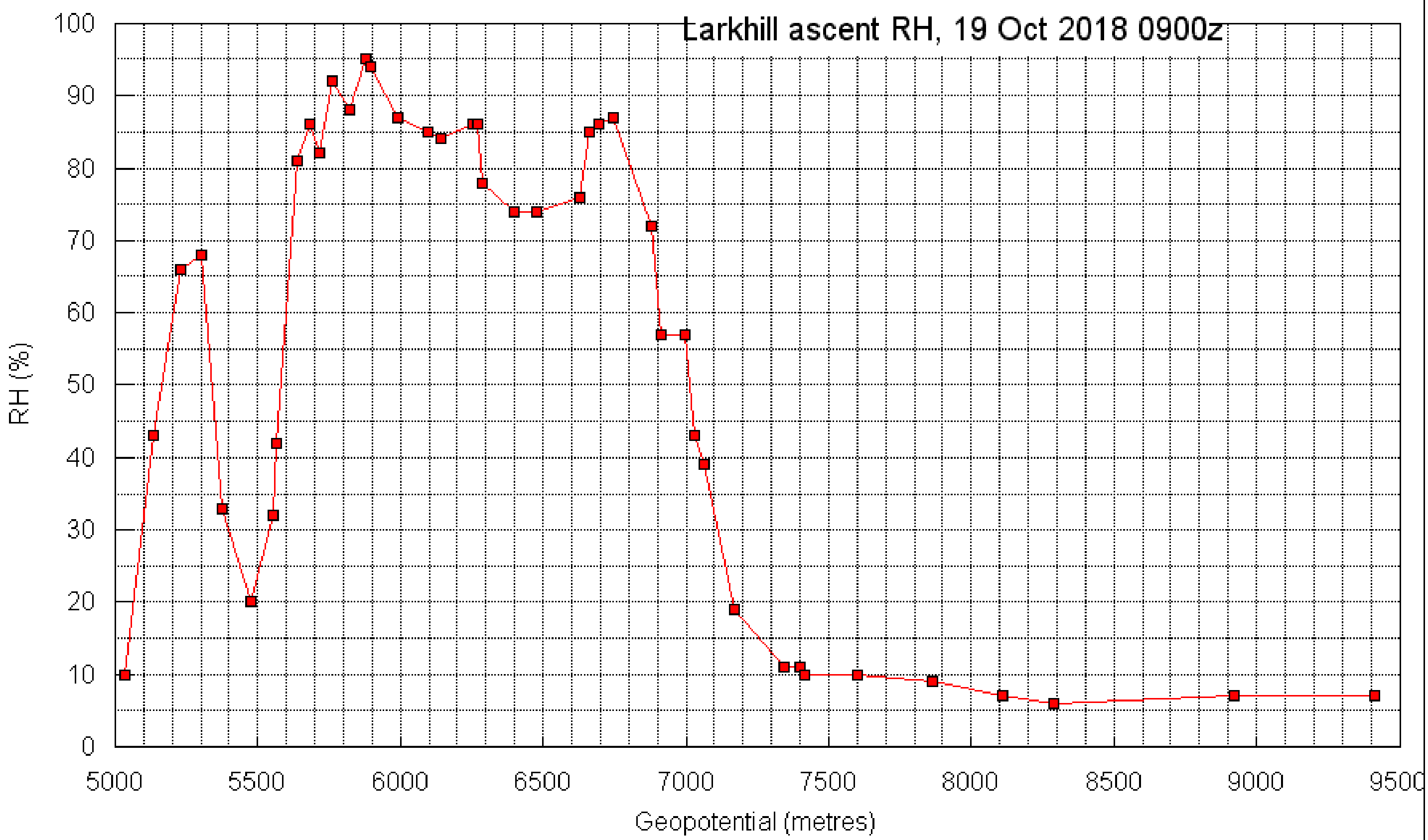
PWAT 15.80
09Z 19 Oct 2018
University of Wyoming

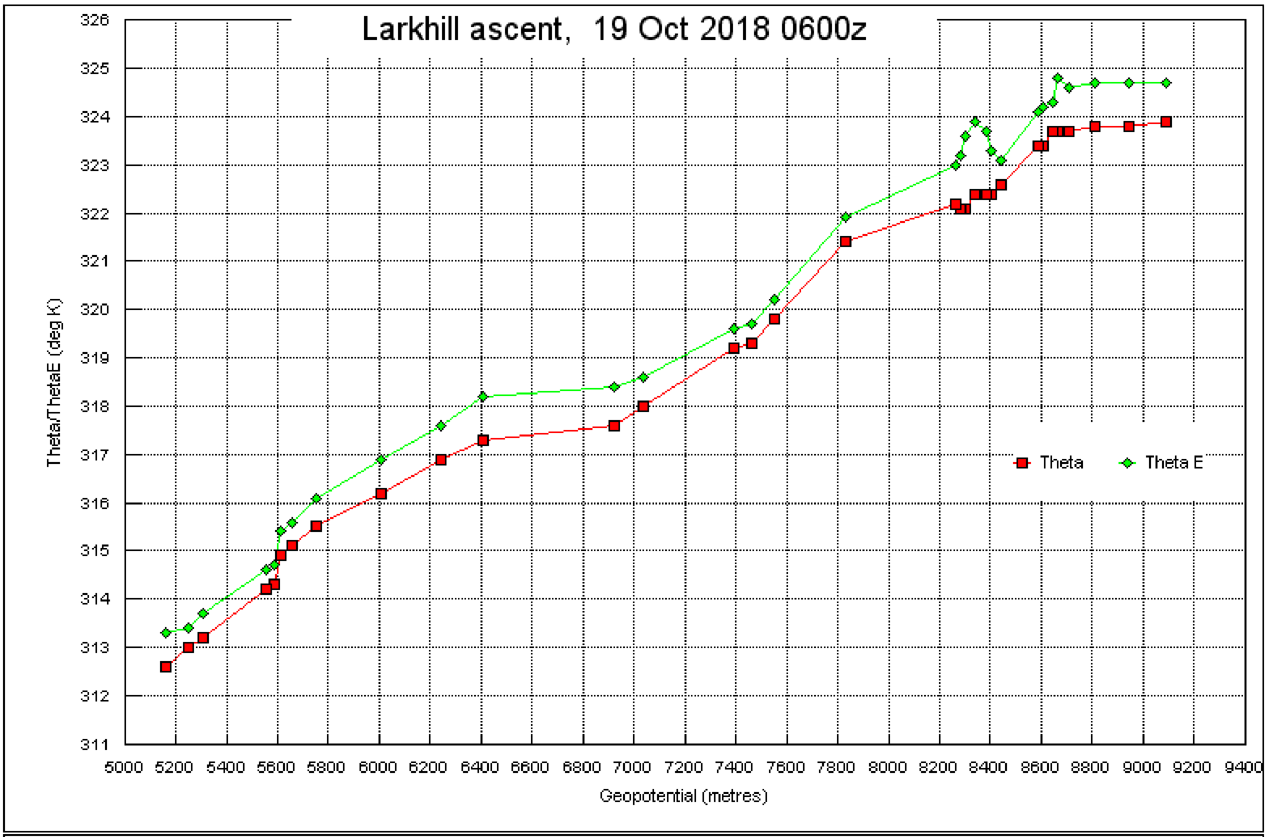
Fig 10

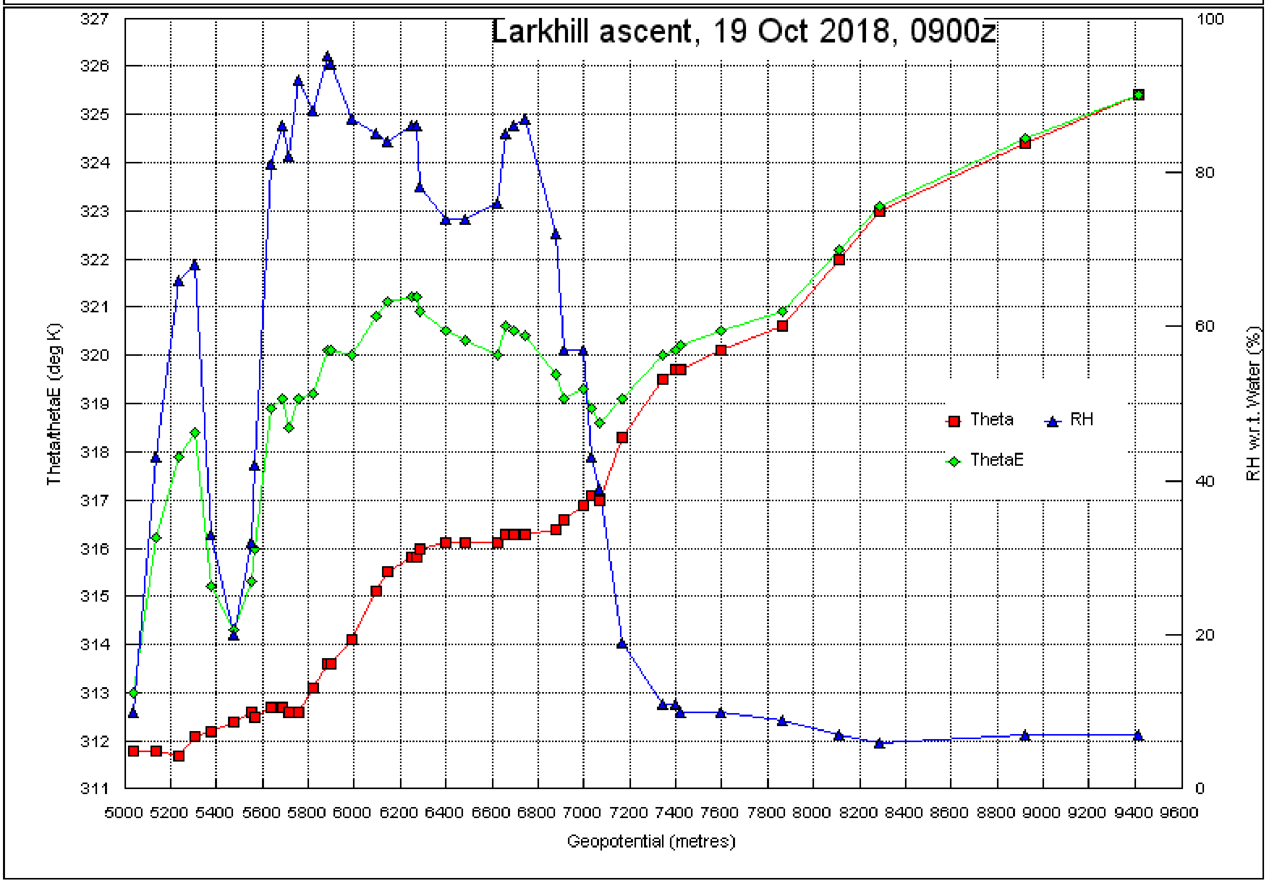


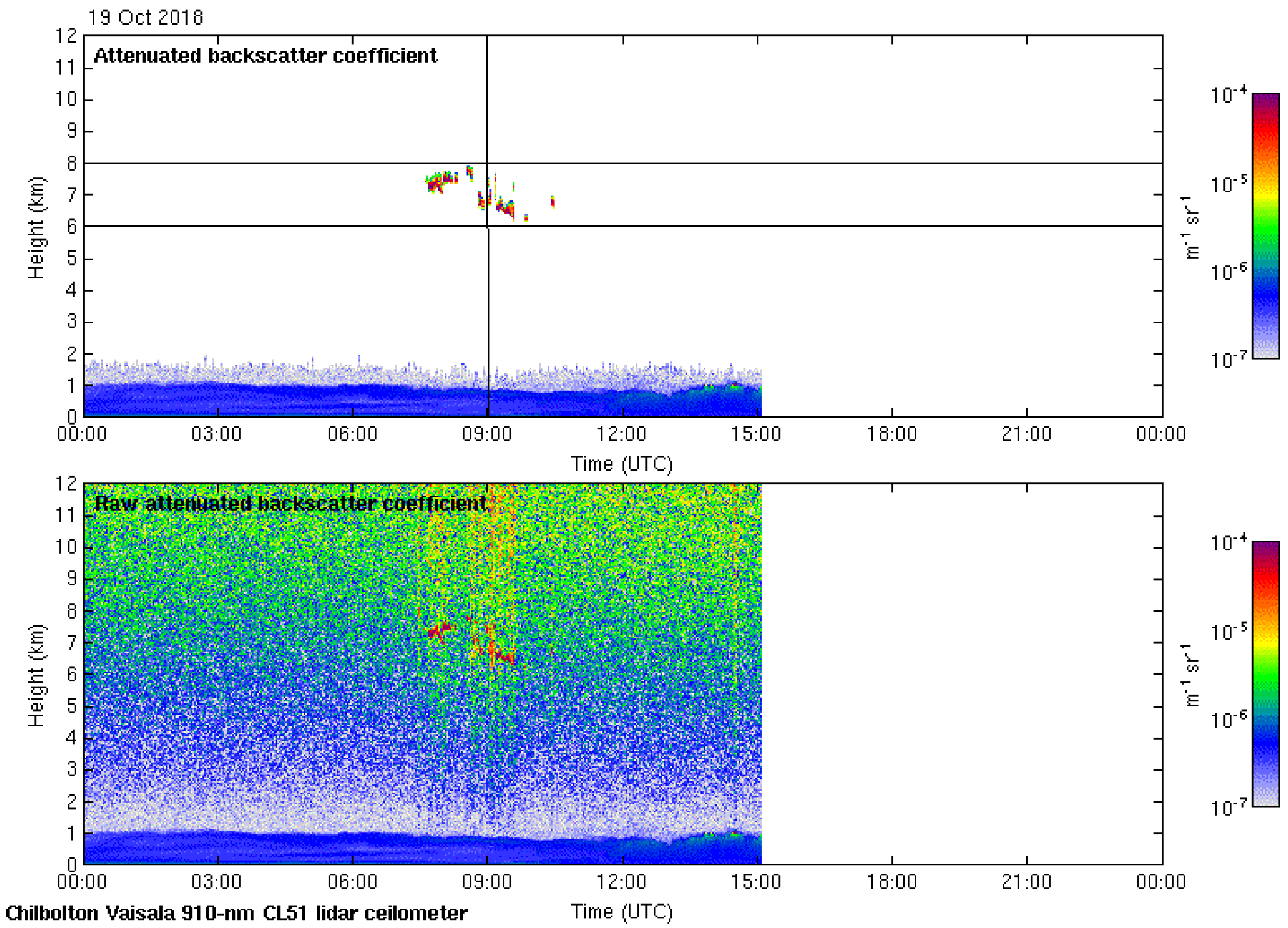
Larkhill ascent RH, 19 Oct 2018 0600z
RH (%)
Geopotential (metres)
0
10
20
30
40
50
60
70
5000
5500
6000
6500
7000
7500
8000
8500
9000
9500

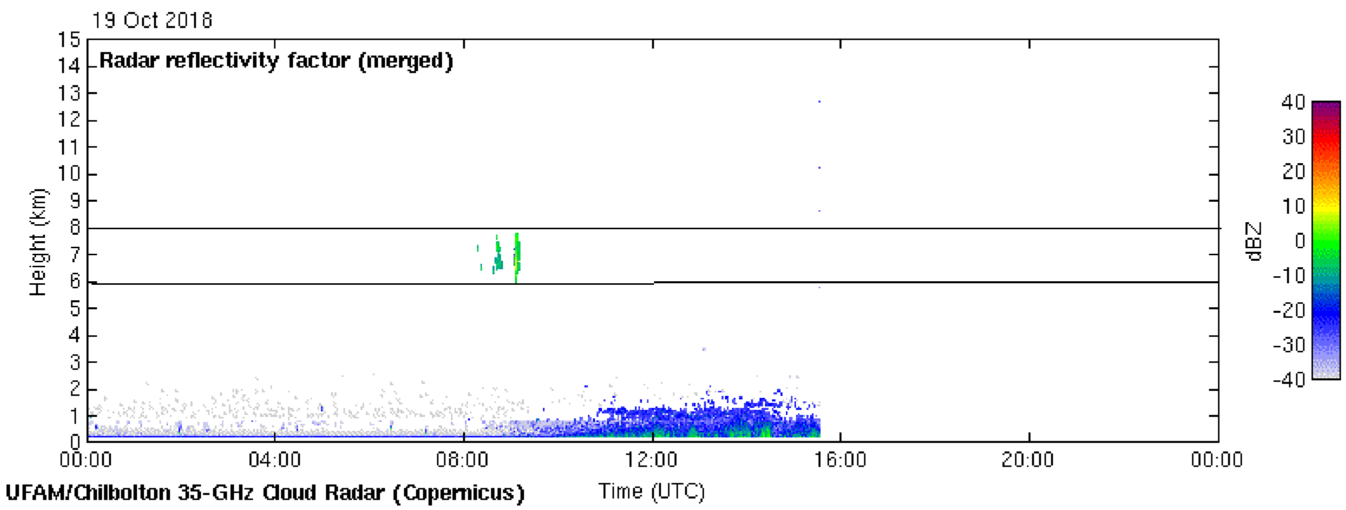



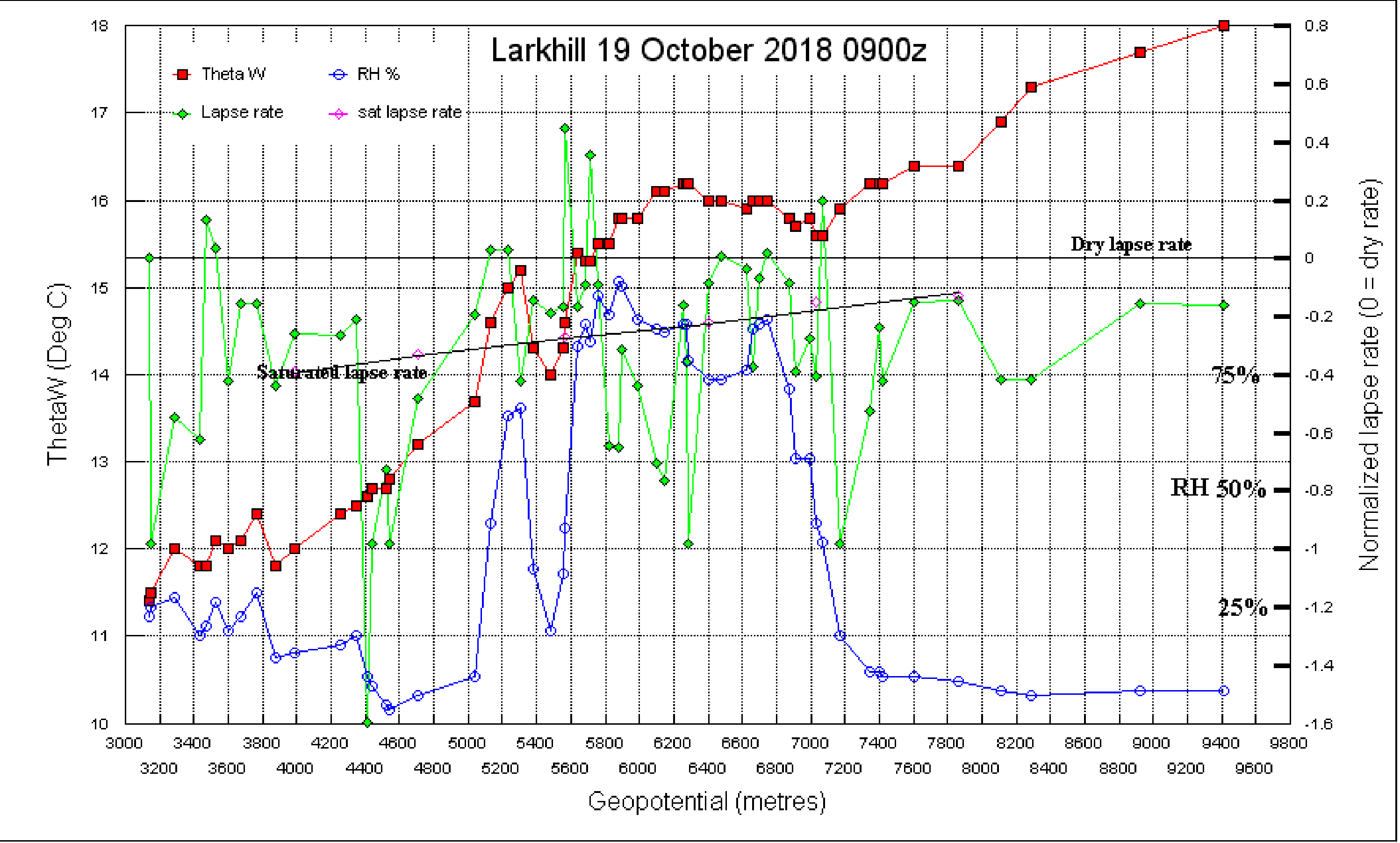
Larkhill ascent RH, 19 Oct 2018 0900z
RH (%)
Geopotential (metres)
0
10
20
30
40
50
60
70
80
90
100
5000
5500
6000
6500
7000
7500
8000
8500
9000
9500


Larkhill ascent, 19 Oct 2018 0600z
Theta/ThetaE (deg K)
Geopotential (metres)
Theta
Theta E

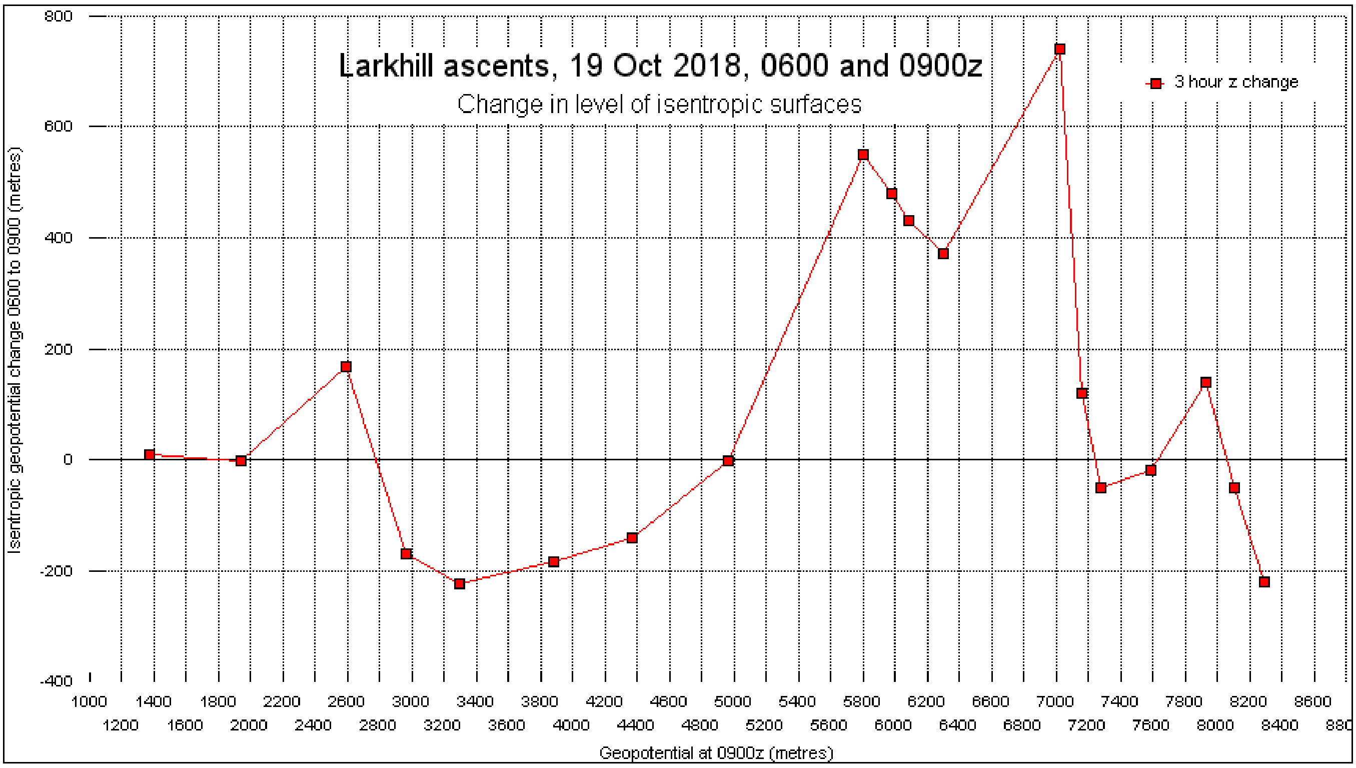

Larkhill ascent, 19 Oct 2018, 0900z
Theta/thetaE (deg K)
RH w.r.t. Water (%)
Geopotential (metres)
Theta
RH
ThetaE


19 Oct 2018
Attenuated backscatter coefficient
Raw attenuated backscatter coefficient
Height (km)
Time (UTC)
$m^{-1}\ sr^{-1}$
$10^{-4}$
$10^{-5}$
$10^{-6}$
$10^{-7}$
00:00 03:00 06:00 09:00 12:00 15:00 18:00 21:00 00:00
Chilbolton Vaisala 910-nm CL51 lidar ceilometer


19 Oct 2018
Radar reflectivity factor (merged)
Height (km)
Time (UTC)
dBZ
40 30 20 10 0 -10 -20 -30 -40
00:00 04:00 08:00 12:00 16:00 20:00 00:00
UFAM/Chilbolton 35-GHz Cloud Radar (Copernicus)



Larkhill 19 October 2018 0900z
Theta W
RH %
Lapse rate
sat lapse rate
Dry lapse rate
Saturated lapse rate
75%
RH 50%
25%
ThetaW (Deg C)
Normalized lapse rate (0 = dry rate)
Geopotential (metres)



Larkhill ascents, 19 Oct 2018, 0600 and 0900z
Change in level of isentropic surfaces
3 hour z change
Isentropic geopotential change 0600 to 0900 (metres)
Geopotential at 0900z (metres)
800
600
400
200
0
-200
-400
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200
3400
3600
3800
4000
4200
4400
4600
4800
5000
5200
5400
5600
5800
6000
6200
6400
6600
6800
7000
7200
7400
7600
7800
8000
8200
8400
8600

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# Unusual Cloud – an Investigation

B. J. Burton. Wokingham.

## Introduction.

As I was making my 0900 GMT observation from my home in Wokingham, Berkshire, on the 19th October 2018, an area of cloud was present overhead, with a distinct edge to the east. The whole cloud sheet was moving eastwards. My initial impression was that it may have been high stratocumulus or low altocumulus.

The cloud sheet seemed to be stratiform with distinct elements, some quite large. Figures 1 to 7 show a series of photographs of the cloud and surrounding sky taken between 0840 and 0855 GMT from my rooftop in Wokingham. On more careful perusal of the cloud, I noticed that it was producing virga in places, evident in Fig 7 as a fringe below the retreating edge of the sheet, also in Fig 3, taken looking nearly vertical, which seems to be a partially filled fall-streak hole with virga appearing as a grey patch obscuring the stratiform cloud elements.

To the west of the cloud sheet there were a number of convective elements producing virga, in the form of cirrus castellanus and floccus, seen in Figures 4 to 6.

To assist in this investigation, sources of data in addition to the visual evidence, were sought. Lidar data from the instrument at Reading University, located 7km west of my house, was available, as was that from the lidar and 35 GHz instruments at Chilbolton, 60km to the west-southwest of Wokingham. Fortuitously, there was also a radiosonde ascent for Larkhill, 73 km west-southwest of Wokingham, nominal time 0900 GMT. Finally, using my weather satellite receiver, I have access to a continuous stream of image data from the Meteosat MSG4 geostationary satellite.

A MSG4 image for 0900 GMT combining the visible and IR channels and showing the south of England is shown in Fig 8. The ascent for Larkhill at 0900 GMT is shown plotted on a skew-T diagram, together with another ascent made at 0600 GMT, these are shown in Fig 9. Figure 10 shows the detailed structure of relative humidity recorded on the 0600 and 0900 GMT Larkhill ascents, plotted against geopotential. Plots of Theta and ThetaE and ThetaW from the Larkhill ascents are shown in Fig11 and 13. The data from Chilbolton lidar and 35 GHz radar are shown in Fig 12. The 3 hour change in isentropic levels between the 0600 and 0900 GMT Larkhill ascent is shown in Fig 14.

## The Height of the Stratiform Cloud

As stated in the introduction, initial impressions could have put the stratiform cloud sheet in the high Sc/low Ac level. However, noting that the 0° C level was near 10000 ft, and that virga was associated with the cloud, the probable height for the cloud base would have been well above this. Turning to the data for the Reading University lidar, at the time of the photographs, returns were being detected for heights between 5.7 km and 7.4 km altitude (above station level, ~60 m ASL). So the stratiform cloud could not have been below 5.7 km , 18600 ft, but could have been as high as 7.4 km or higher (the Reading lidar upper limit is near 7.5 km), that is 24300 ft or higher.

Looking at the satellite image, Fig 8, the stratiform sheet is part of a band, with a curved leading (easterly) edge, as can also be seen in Fig 7. The portion of the cloud field over Wokingham is 29 km wide, with convective elements extending 93 km to the west of the band. At the time of the image, 0900 GMT, both Larkhill and Chilbolton were under the field of convective elements seen also in Figs 4 to 6. This should be borne in mind when viewing the ascent data for Larkhill.

A careful look at the Chilbolton lidar, Fig 12, clearly shows the sequence of stratiform band then convective elements. The first echo appears at 0735 GMT, and the last at 1021 GMT. Noting the sequence of events at Wokingham and the satellite image, the stratiform sheet, which was moving from a generally WNW direction, is clearly preceding the convective elements, and would have been the earliest returns from the Chilbolton lidar, between 0735 and ~0830 GMT, and the base of these span the height interval 7.0 to 7.5 km, 23000 to 24600 ft, with a temperature between -25 and -30°C. Bearing in mind that some of the lowest returns could be from virga at both Reading and Chilbolton, the stratiform cloud seen in Figs 1 to 3 would fit the evidence best at a height of ~24000 ft. The time of arrival of the cloud band over Chilbolton and over Wokingham differed by 1.2 hours. This equates to a rate of advection of 13.8 m/sec appx., and the winds measured by the 0600 and 0900 GMT ascents for Larkhill near the 7.5 km level were 290° 14 and 12 m/sec respectively, supportive evidence for the altitude of the cloud being at this level.

The Field of Convective Elements.

Figs 4 and 6, looking to the west, and 5 looking to the NW, clearly show the convective nature of the regime immediately to the west of the stratiform band. It was this region that the Larkhill 0900z ascent would have sampled. The height of the cloud on the Chilbolton lidar data lies entirely between 6.1 and 8.0 km, 20000 to 26200 ft. It is fair to assume that most if not all the returns from the lower levels were from virga, much of which can be, from Figs 5 and 6, seen to be dense and copious. Very rough measurements on the cloud photographs, assuming the cloud tops are near 8.0 km, gives the base of the virga near 5.5 km., in approximate agreement with the lowest returns from the Reading University lidar of 5.7 km.

The isolated convective element near the centre of Fig 5 is particularly interesting as it could be observed to be actively developing out of a clear sky. There is another similar element nearer the right-hand edge of the line of castellanus in the same figure, that was also growing visibly. It is possible from the 0900 Larkhill ascent, Fig 13, that these isolated elements could have developed below the main convective region, as a thin convective layer existed between 5100 and 5600 m. The base of this layer is characterised by a dry lapse rate overlain by a decrease in thetaW, indicating potential instability. Although the RH at the top of the dry lapse rate is below 75%, it is possible that spatial and temporal changes in the RH regime at this level could have produced saturation and the dry but potentially unstable layer near 5500 m could have led to the isolated convective elements seen in Fig 5. Vertical wind shear was examined to look for low RI stable regions capable of supporting billow clouds, but wind speeds are modest, and there are not any layers with strong shear. However, of interest, though it is above the probable level of the cloud, the shear vector rotates from 264 deg at 7000 m to 187 deg at 7500 m to 315 deg at 7800m.

The returns from the 35 GHz radar span the height interval 6.0 to 7.9 km, and the time interval 0815 to 0909 GMT, whereas the lidar echoes span the time interval 0735 to 1021 GMT. Assuming the cloud motion was constant and that the width of the stratiform band was 29km when it passed over Chilbolton, the band would have passed over in appx 40 minutes, between 0735 and 0815 GMT. As the first 35 GHz return is near 0815, it seems that it was only picking up the densest elements in the convective regime. It may be that the radar performance was sub-optimal on this occasion, as under normal circumstances I would have expected it to have shown much more of the cloud seen by the lidar.

It is evident from the ascent diagrams, Fig 9 and 10, that there is a moist layer >80 % RH wrt water from 5620 m to 6800 m altitude on the 0900 GMT Larkhill ascent. The corresponding temperature range is -17 to -24 °C, and it is within this layer that the convection was being initiated.

What is interesting about the 0900 ascent is that the layer where the stratiform cloud existed, as seen on the Chilbolton lidar near 7.5 km, has become, by 0900 GMT over Larkhill, very dry, ~10% RH.

Fig 13 shows a plot of Lapse Rate, Theta W and RH against geopotential. The layer of interest lies between 6180 and 7400 m. At the base of this layer, thetaW, which had been increasing with height, now begins to fall. This marks the base of a potentially unstable layer wherein, should condensation occur will lead to convective ascent until a level is reached where the value of thetaW equates to that at the base, namely 7400 m. Convective cells on reaching this level will experience stable surroundings and will decelerate. However, when cells reach ~6800, the RH starts to fall from its high values, dropping below 60% at 7000m, and by 7400 m is only around 10%. Thus any convective cloud would soon mix with the dry surroundings, with evaporation of the existing cloud particles reducing its buoyancy.

Looking now at the Lapse Rate profile, Fig 13, we see that from 6400 to near 6900m, it is close to the dry rate, and this layer can be considered as being conditionally unstable. It almost certainly is within this layer that convection would be initiated. Cloud would form easily in the moist but stable environment from 5800 to 6400 m, 95% RH wrt water at 5900m, especially if orographic waves were present. The humidity profile below 6200m, Fig 10 (lower) is moist to around 5600m, and evaporating virga would have contributed to this moisture. Once the layer near 6200 m became saturated, convection would ensue, potentially reaching 7400 m. The images, Figs 4 and 5, might suggest that orographic forcing could have produced the elongated castellanus features containing these features.

<u>The 0600 GMT Larkhill ascent.</u>

The profiles of the 0600 GMT Larkhill ascent, Figs 10 (upper) and 11 (upper) are, perhaps surprisingly, very different from the 0900 GMT ones, Figs 10 (lower) and 11 (lower). The changes in the moisture profile is especially marked, with the moist layers between 5000 m and 7000 m on the 0900 ascent replacing an extremely dry regime, containing a minimum RH of 3% at 5500m and a maximum of 16 % at 6900 m, on the 0600 GMT ascent. Also, the moist layer above 8400 m on the 0600 GMT ascent has been replaced by very dry air, RH <10 % by 0900 GMT.

The satellite image, Fig 8, shows that the band of stratiform upper level cloud extends over the Humber to the North Sea, but terminates in the south close to the Isle of Wight. The history of this cloud band, from the overnight IR satellite images, shows it to be the remnants of a a broader band of upper cloud over the Irish Sea at 19/0000 GMT, this band being part of a frontal system extending northwards over Faeroe and eastern Greenland in the circulation of a low west of Iceland. South of 60N this frontal system showed 'split front' characteristics, the lower cloud band extending southwards past the west of Ireland, and crossing 50N near 18W, linking to a frontal wave near 51N 35W.

3 hourly Water Vapour imagery reveals a complex pattern over southern UK. An upper trough at midnight on the 19$^{th}$ lay over the area but contained two well developed mesoscale vortices., 'A' and 'B'. 'A' lay over the coast of Norfolk and 'B' over the central Welsh Border. By 0900 GMT 'A' had moved across the North Sea to be near the Dutch coast and 'B' lay over the coast of Norfolk. So the air sampled by the 0600 GMT Larkhill ascent was on the western flank of vortex 'B' and just west of the axis of the upper trough. The band of moisture associated with the upper part of the split front can be seen at 0600 GMT lying from North Yorkshire to Devon.

The upper pattern, then, was very complex, which goes some way to explaining why such large changes occurred over central southern England in the 3 hours between 0600 and 0900 GMT. To attempt to analyse the detail of the upper wind/height contours on the mesoscale is a fruitless task due to the paucity of upper air data, none apart from Larkhill at 0600 GMT, and spacing between routine soundings at 0000 GMT large enough to preclude an analysis on the mesoscale.

Some insight into the dynamics associated with this complex set up can be gleaned from the 3 hour changes over Larkhill on the 19th. From the theta data for the 0600 and 0900 GMT ascents, the change in the height of selected isentropes can be calculated. This has been plotted in Fig 14. Here we see that the layers of interest containing our clouds, from 5000 to 7200 m, underwent very strong positive change, the height of all isentropes increasing between 500 and 700 m. Below these levels, there was a modest decrease in height of isentropes of around 200m between 3000 and 4500 m. Although it is not possible to infer that these changes equate to vertical motions, the presence of the cloud that is the subject of this article, and the humidity structure at 0900 GMT, does indicate that dynamic vertical motion was involved

## Conclusion.

The foregoing examination of the available data on the morning of the 19th October 2018 over southern England leads to the conclusion that the stratiform cloud seen in Figs 1 to 3 and 7 is indeed much higher than it appears both from the images and from my own visual observation. The most probable height for this cloud was between 7.0 and 7.5 km, and likely to have been near the top of this range, near 24000 ft, with a temperature not far above -30 °C. The satellite image, Fig 8, shows that the stratiform cloud was part of a band stretching roughly north-south over eastern UK, though the band orientation changed to NE to SW over southern England, and the band ended over the English Channel south of Portland. Satellite image sequence (not shown) shows that this band was associated with the upper part of a split cold front moving east, the lower part being located well to the west.

To the west of the band of stratiform cloud there was a field of high level convection, as seen in Figs 4 to 6. The sequence of lidar echoes from the Chilbolton Observatory, located 60 km west-southwest of Wokingham, indicated that the stratiform cloud sheet was at a similar but slightly higher height than the convective elements, approximate mean heights for the echoes being 7.5 km and 6.6 km respectively. The time difference between the first lidar echoes at Chilbolton, and the arrival of the stratiform cloud over Wokingham gives an approximate speed of movement of 13.8 m/s, which agrees with the wind at 7.5 km of 13 m/s (mean of 0900 and 0600 GMT Larkhill ascents).

Analysis of the 0900 GMT Larkhill ascent, Fig 13, shows that the layer between 5300 and 5600 m can support convection, but is dry between 5350 and 5600. The isolated convective elements seen in Fig 5 could be forming in this layer. The region between 5800 and 6400 m is moist and stable, but the thetaW profile shows that it is potentially unstable between 6200 and 7400 m. The lapse rate is dry or near to it from ~6400 to 6800 m, but the atmosphere dries out markedly above 6800 m. Some layered cloud could be expected between 5800 and 6400 m, which would be expected to convect energetically above 6400m, with isolated tops reaching above 7000 m. This is most probably the cloud seen in Figs 4 to 6 which seems to consist of a mixture of layered and convective cloud and also virga. It should be noted that the RH, shown in Figs 10 and 13, is with respect to water, and that between 5700 and 6200 m, is supersaturated with respect to ice.

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The upper air pattern to the east of the clouds discussed in this article was somewhat unusual and complex. Two marked vortices were detectable on the water vapour imagery, moving east in step with the upper trough associated with the stratiform cloud band, the westernmost vortex being over Norfolk at 0900 GMT. The proximity of this vortex may go some way to explain the very large changes that took place over Larkhill in the 3 hours up to 0900 GMT. Isentropic changes over that period, shown in Fig 14, suggest modest descent between 3000 and 5000 m, maximum 200 m, and ascent between 5000 and 7200 m, averaging ~500 m between 5800 and 7100m. It is no coincidence that this is also the layer where high relative humidity is found on the 0900 GMT Larkhill ascent.

B J Burton 29 November 2018