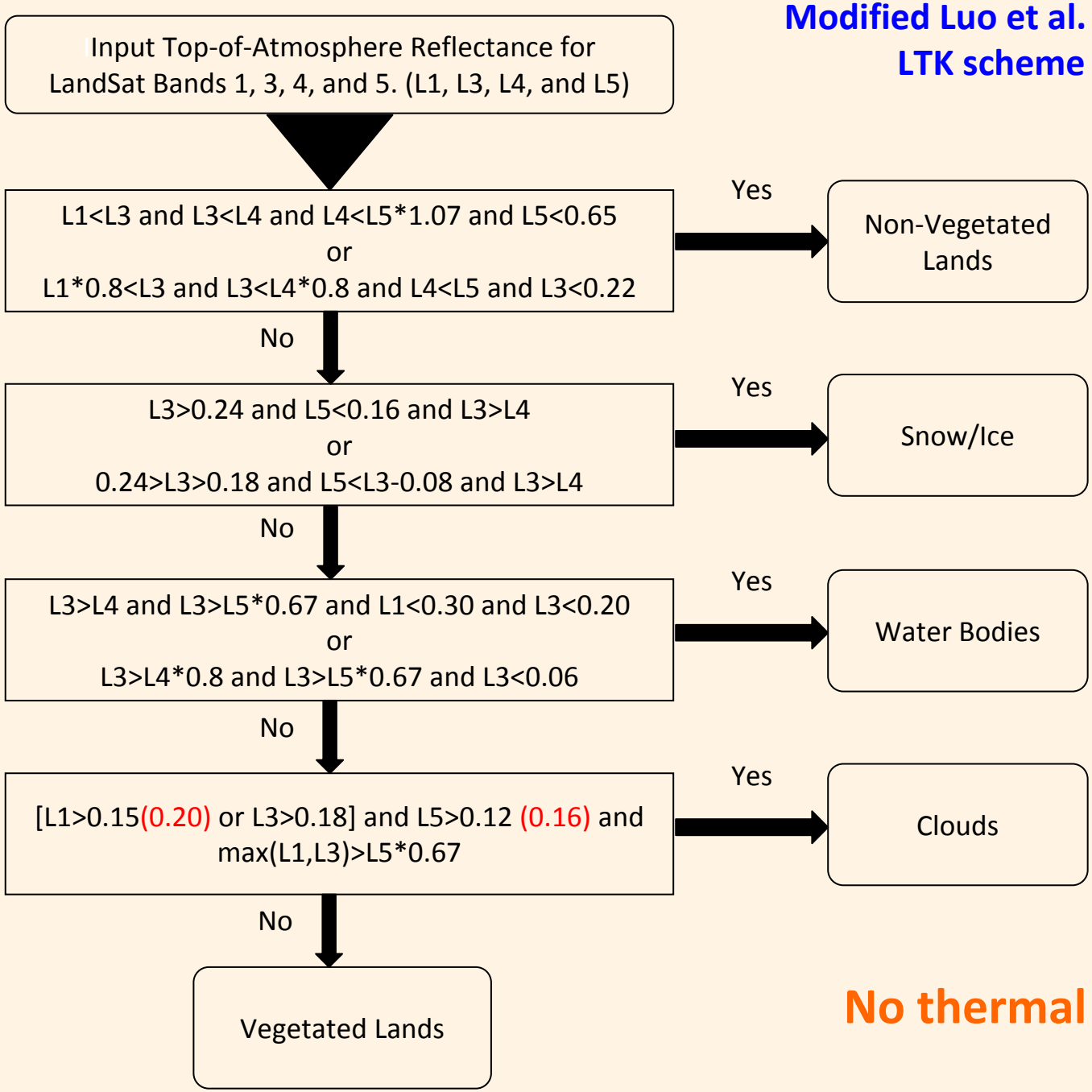
A simple cloud mask algorithm developed for MODIS land bands applied on Landsat scenes

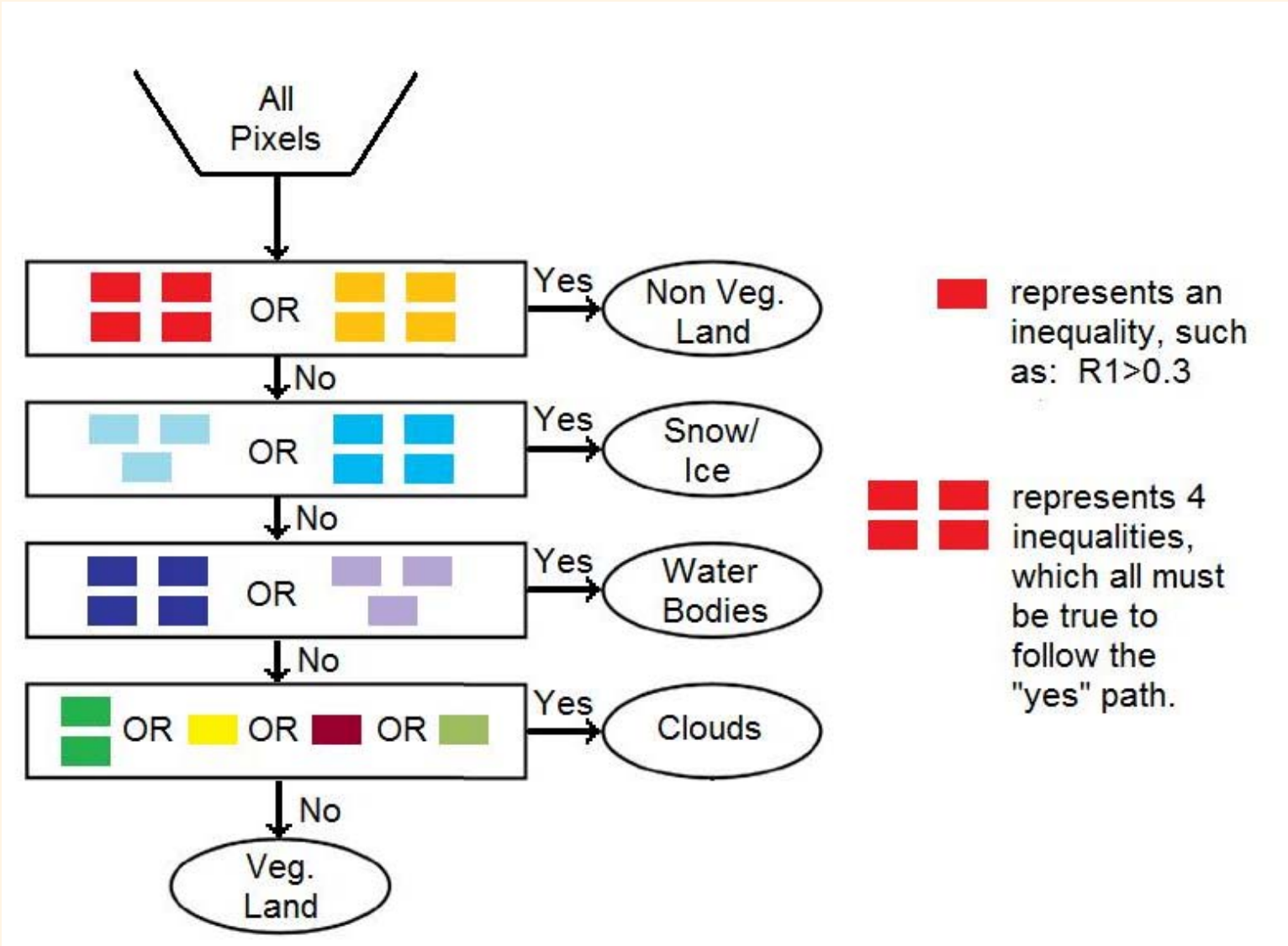
Lazaros Oreopoulos (NASA-GSFC)
and
Mike Wilson (UMBC-GEST)
Tamás Várnai (UMBC-JCET)

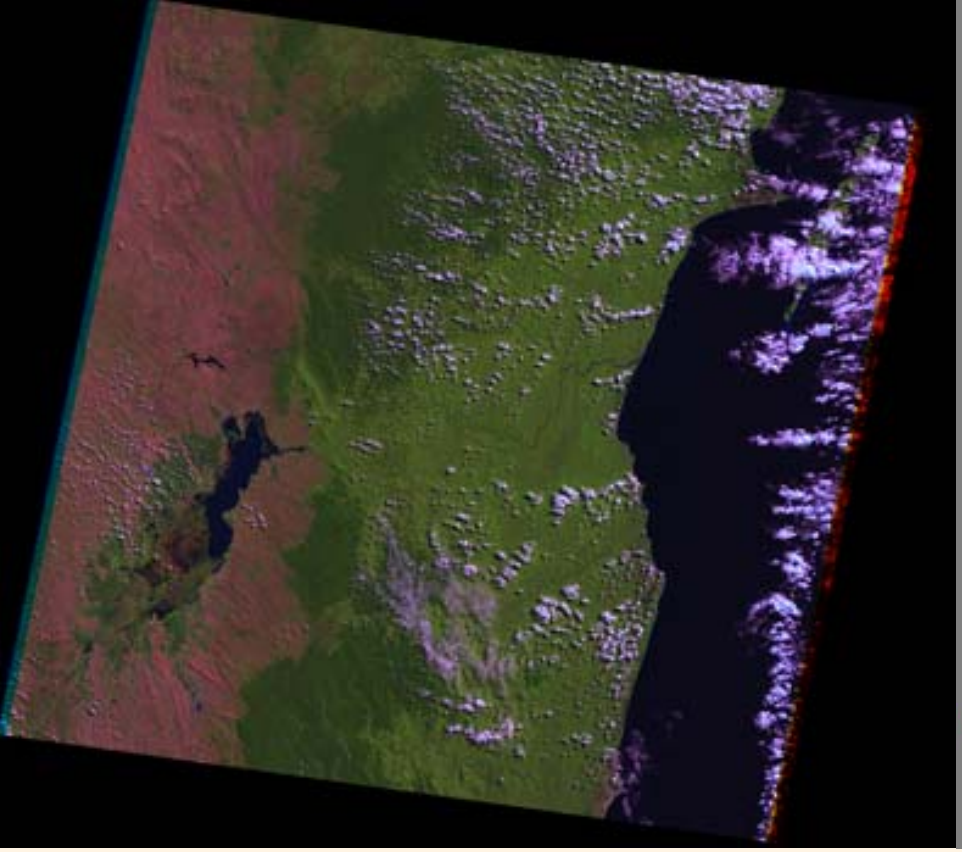
Modified Luo et al. (2008) LTK scheme

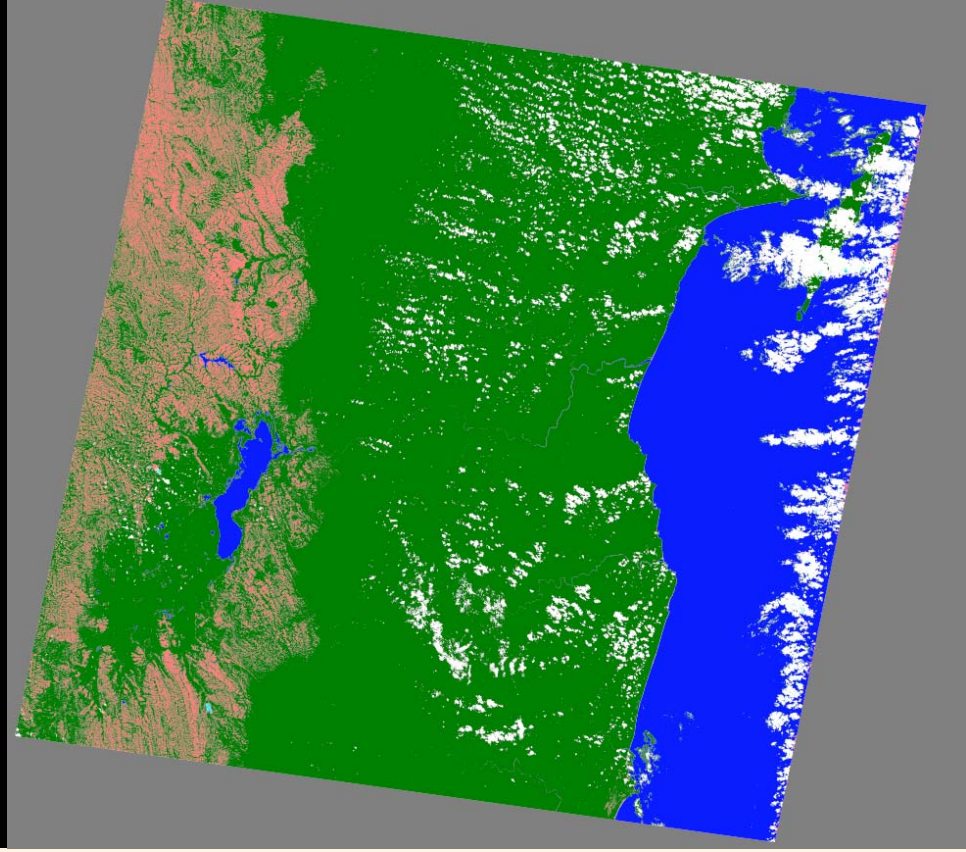


No thermal!

Simplified view of the LTK scheme

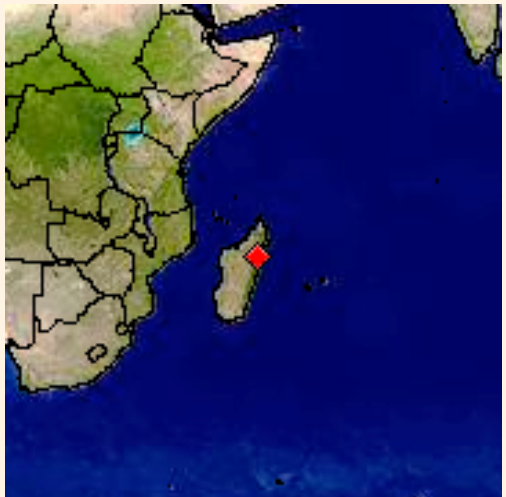






Subtropical South
P158_r72_4

ACCA agreement 95.4%
LTK agreement 91.5%



Non-Vegetated Lands

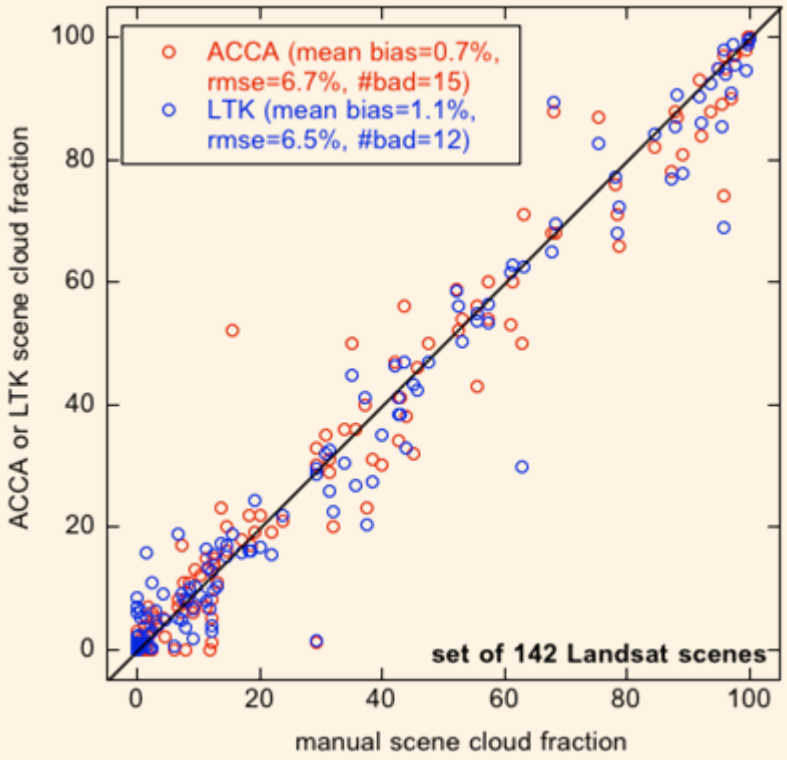
Snow/Ice

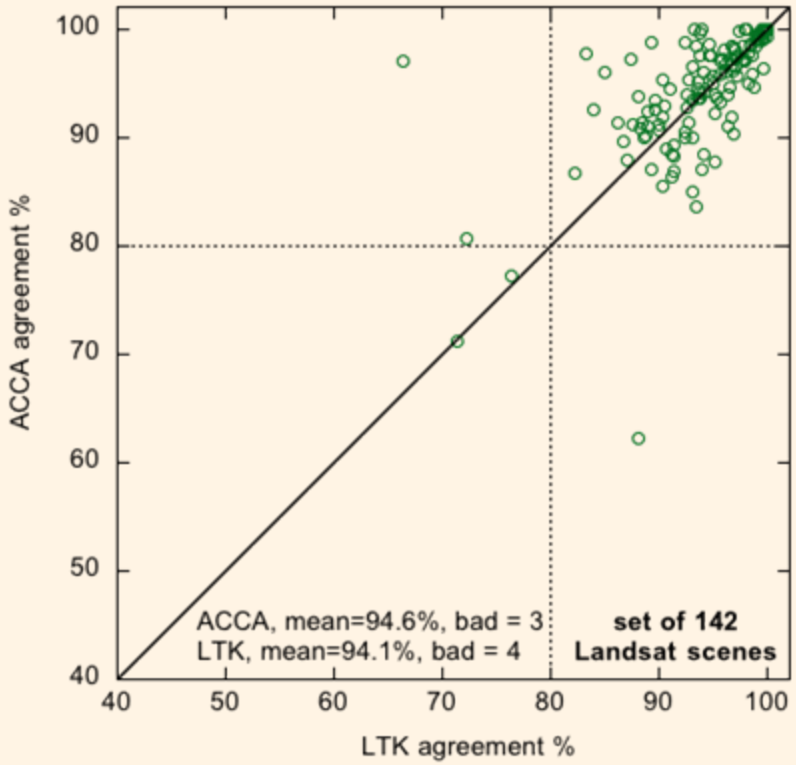
Water Bodies

Vegetated Lands

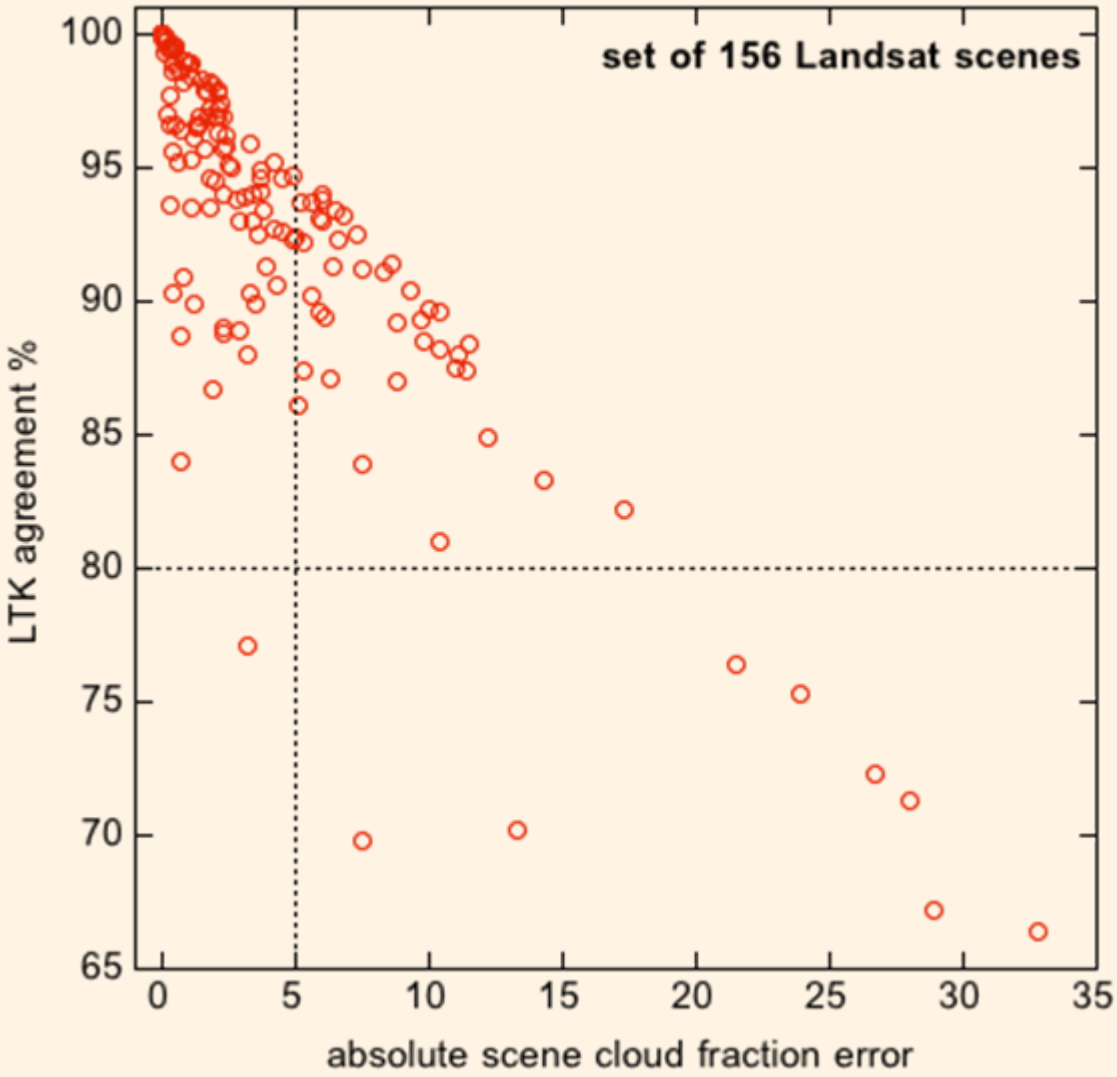
Cloud

Performance comparison between LTK and ACCA
Irish et al. scenes via USGS and BU





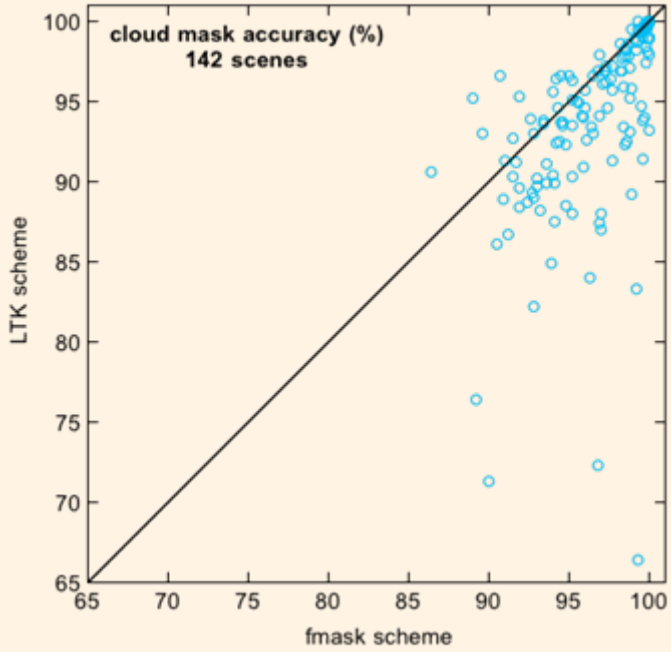
Is there compensation of errors in LTK?



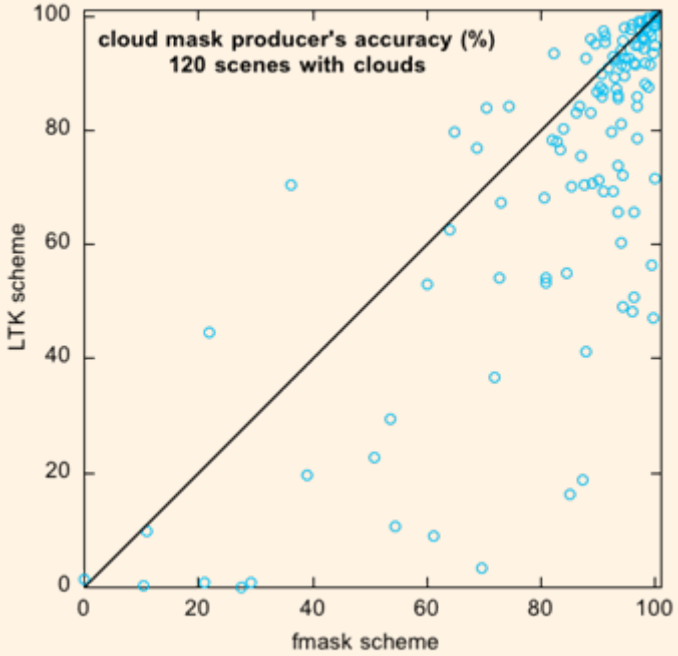
Some facts about our “poor” (19/156) scenes

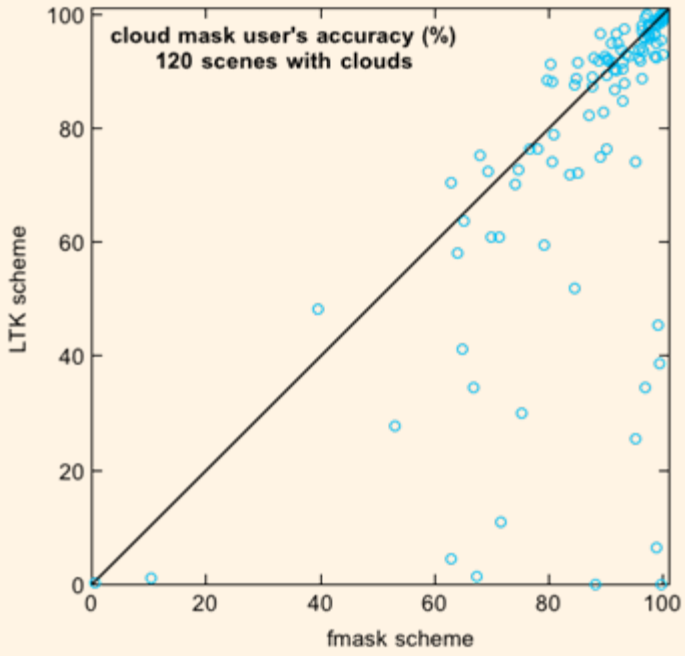
“poor” = either errors in scene CF > 10% or level of mask agreement < 80%

- 5 are from south pole latitude zone
- 7 have >10 % error in manual scene CF between Irish et al. and USGS
- 7 (3 from above) have also ACCA scene CF errors > 10%, i.e, 11 “bad” scenes
- From 11, 6 have < 80% mask agreement for ACCA, and 7 do not belong to BU dataset
- 12/19 have thin cloud amount above the median (0.31) of 134/156 scenes with some cloud

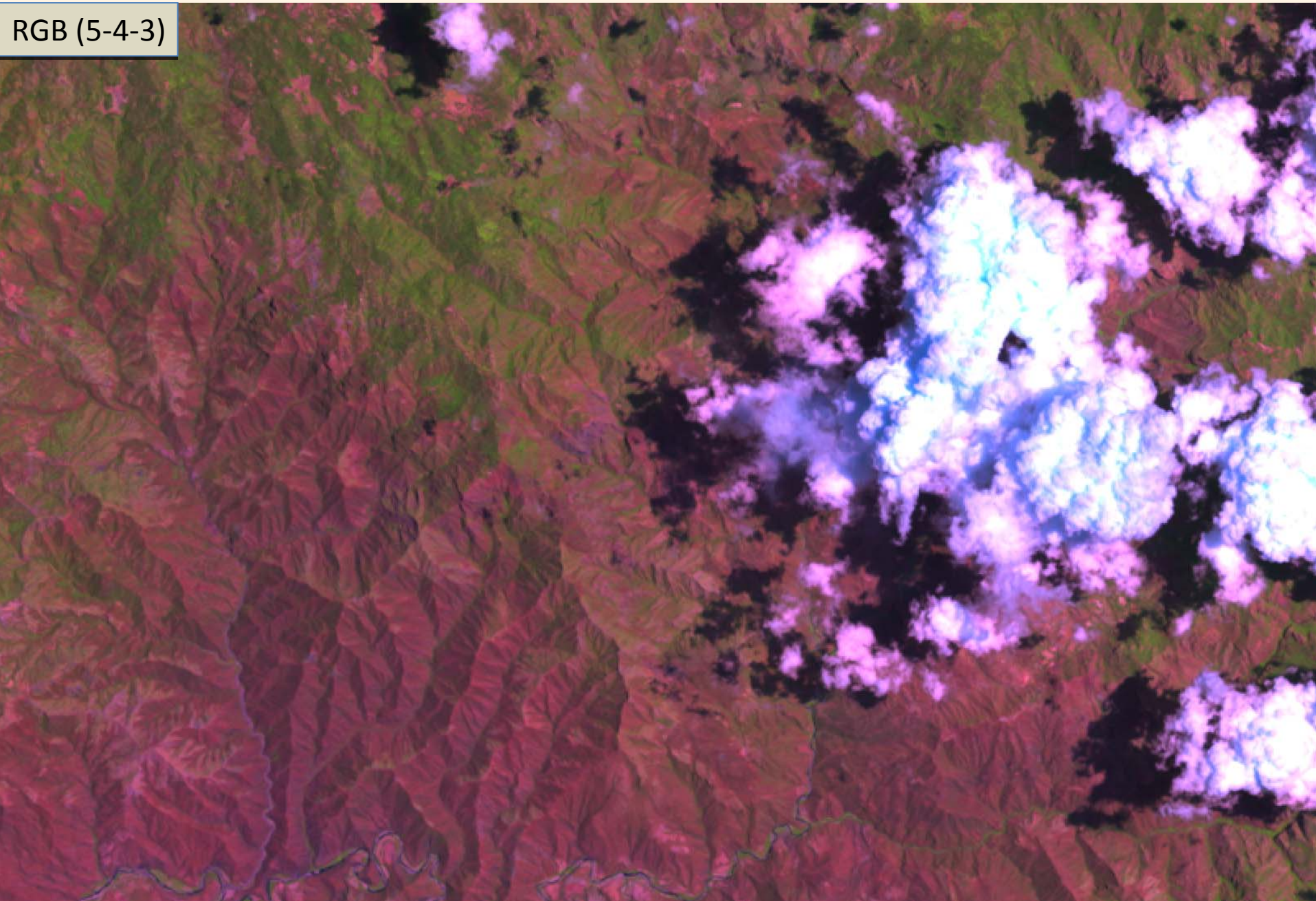


Comparison between LTK and fmask (clouds only)

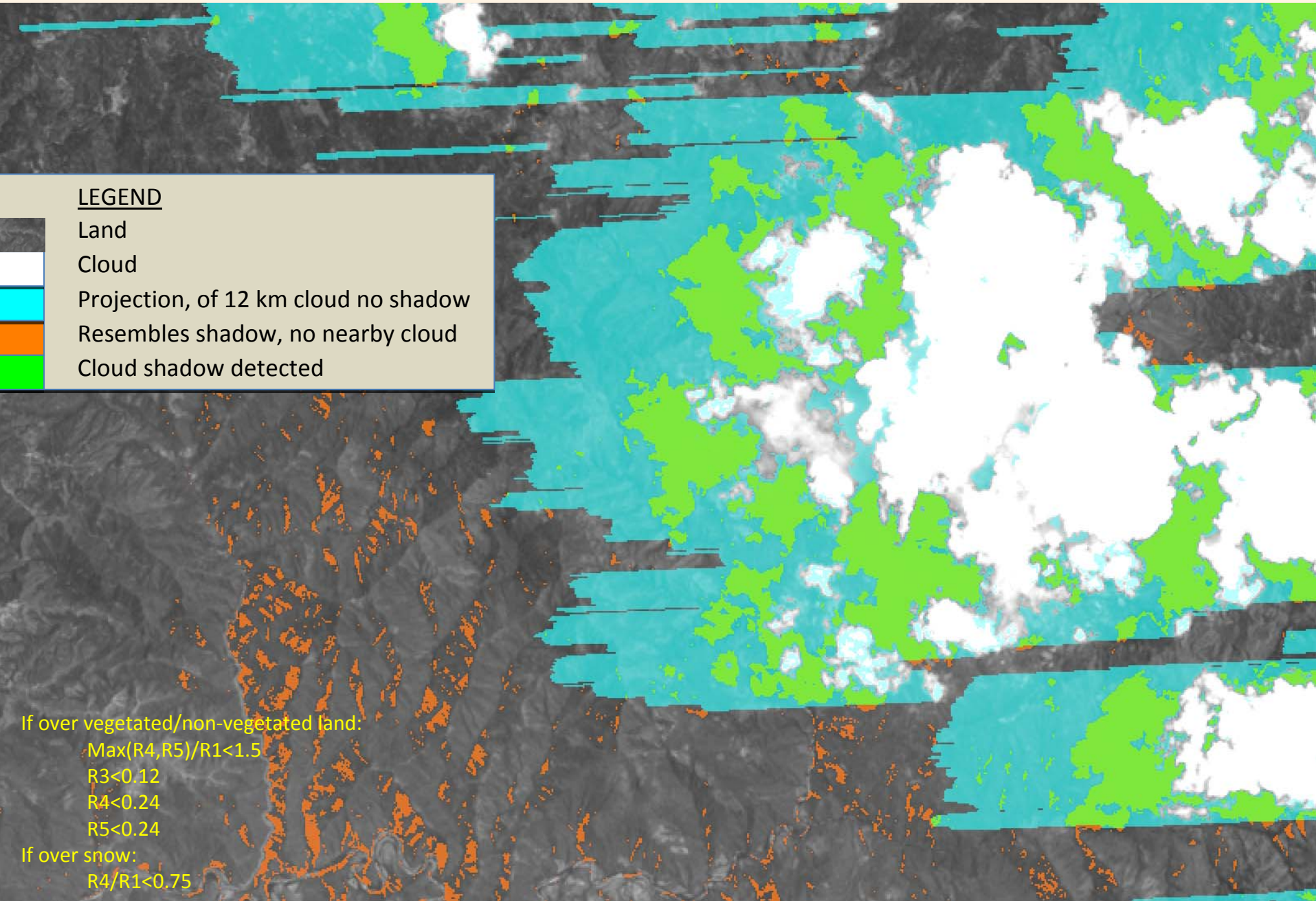


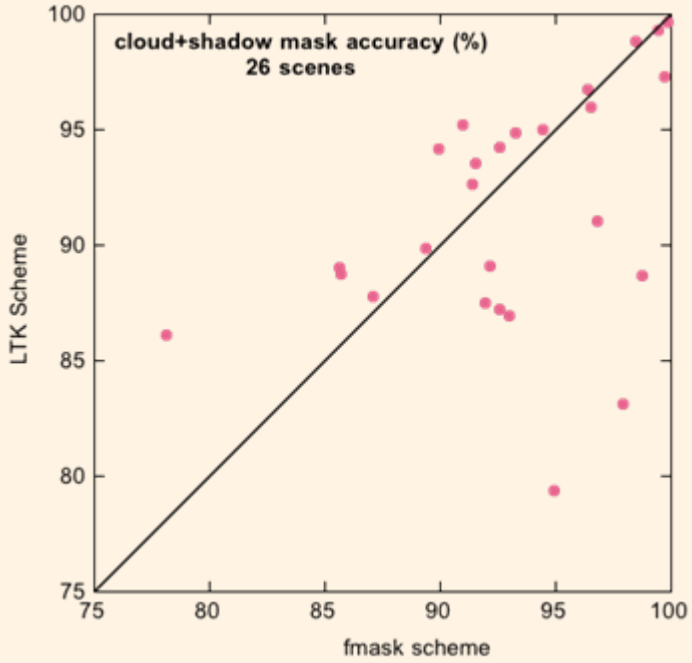


Subtropical North, Path 31, Row 43

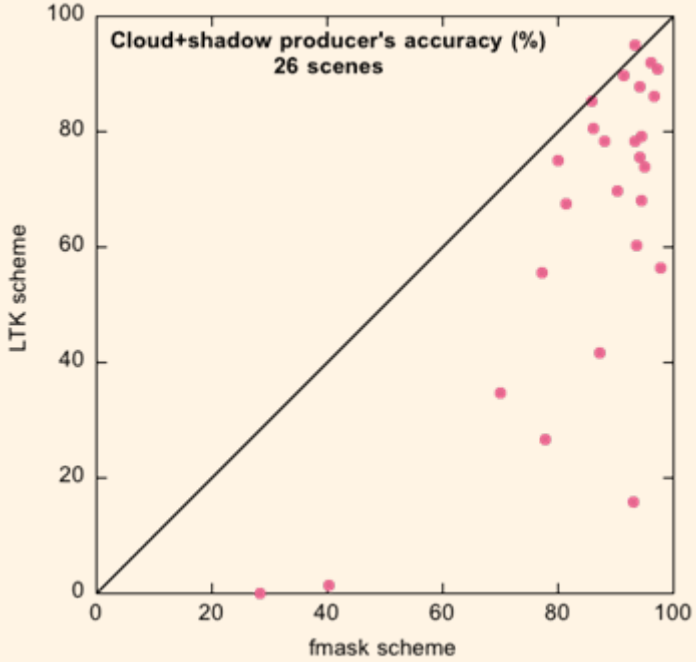


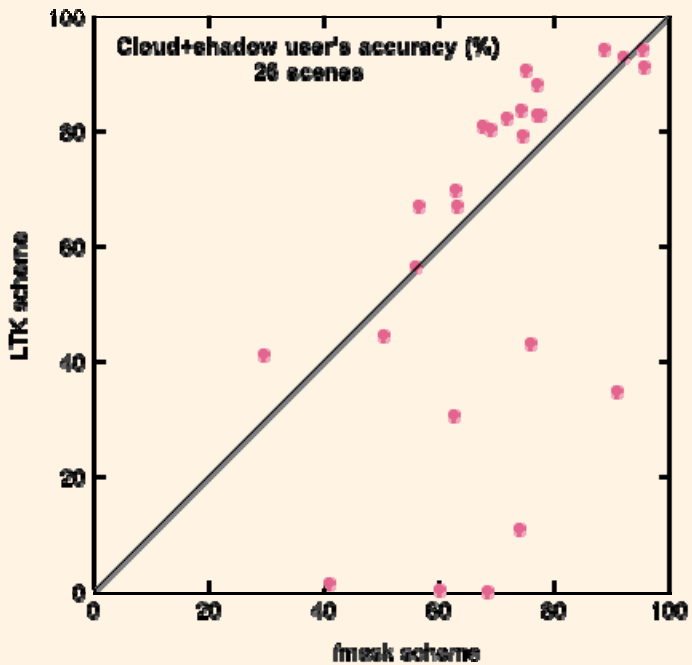
Subtropical North, Path 31, Row 43



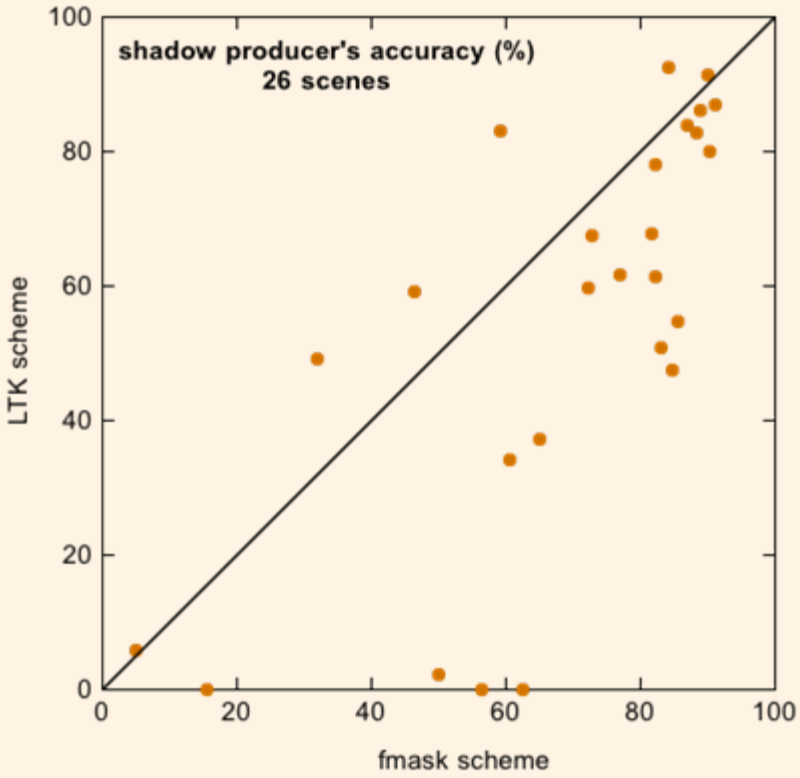


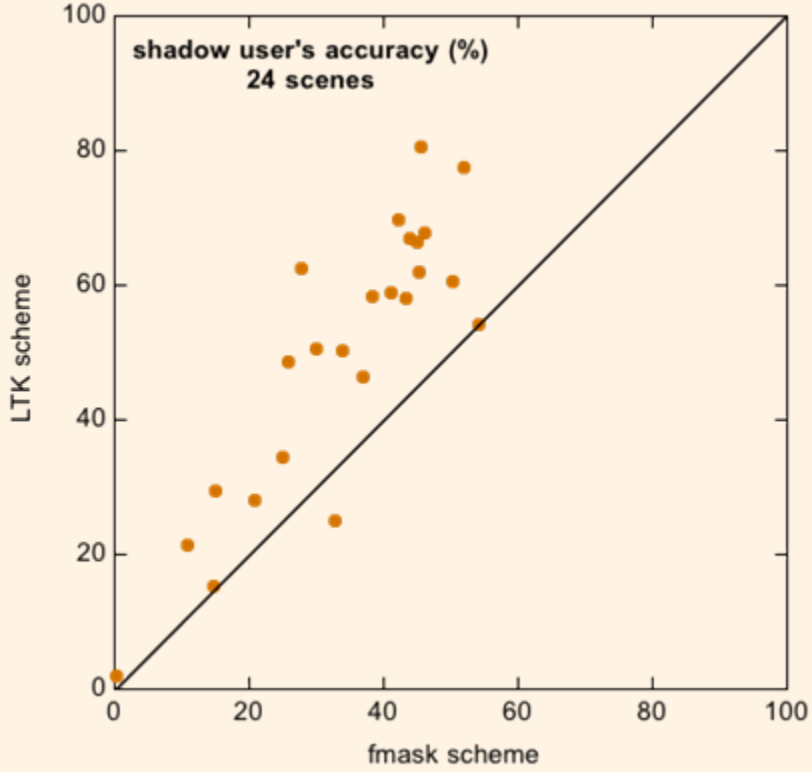
Comparison between LTK and fmask (clouds & shadows)





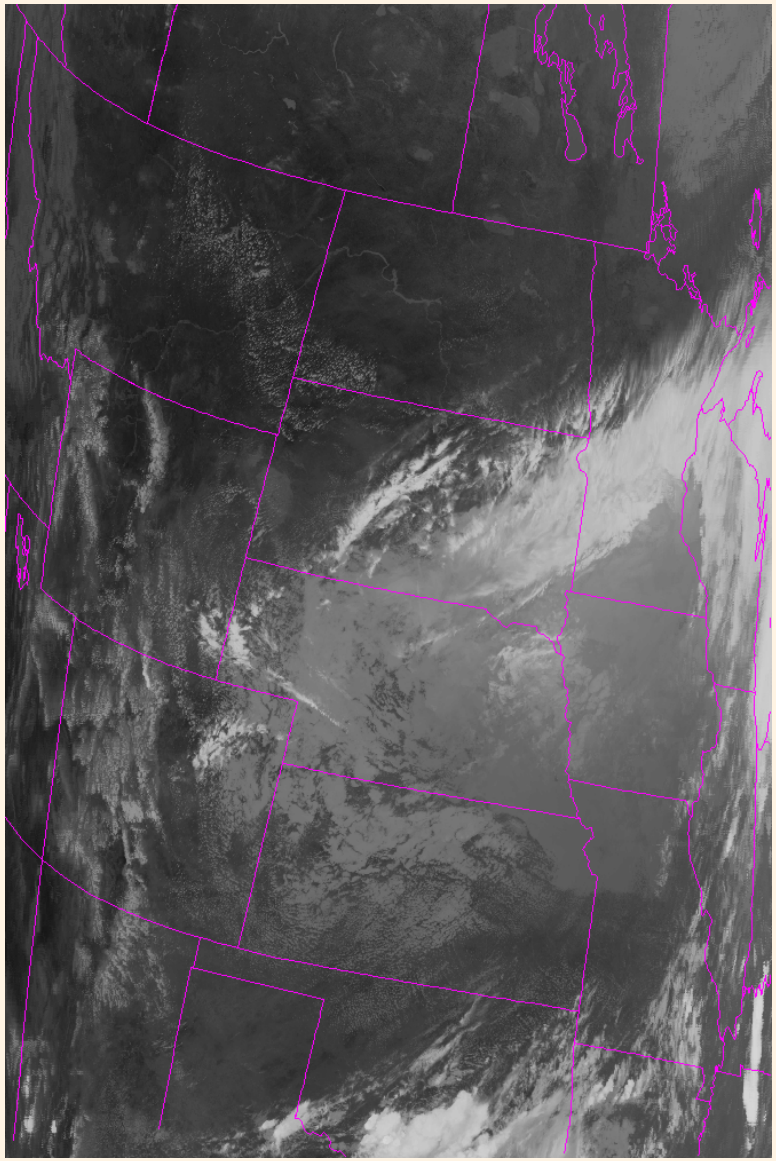
Comparison between LTK and fmask (shadows only)



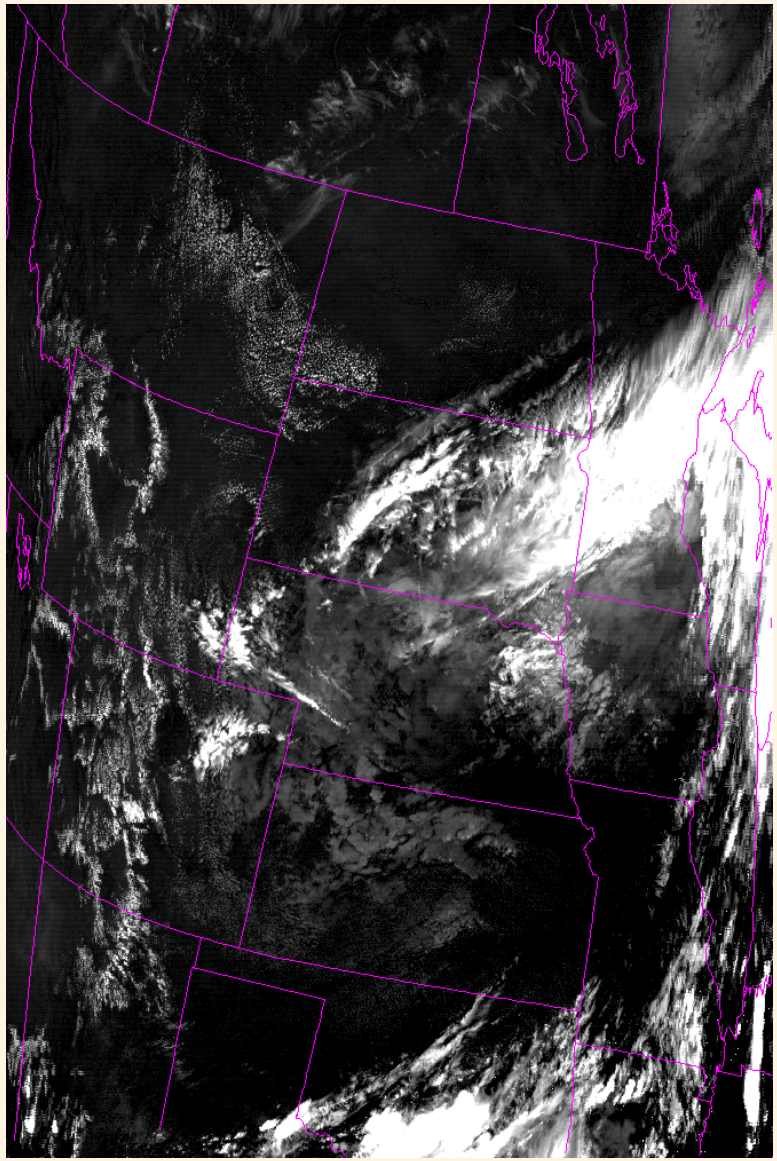


Split window high cloud detection

MODIS 2006240 19:45 UTC (courtesy of R. Frey)

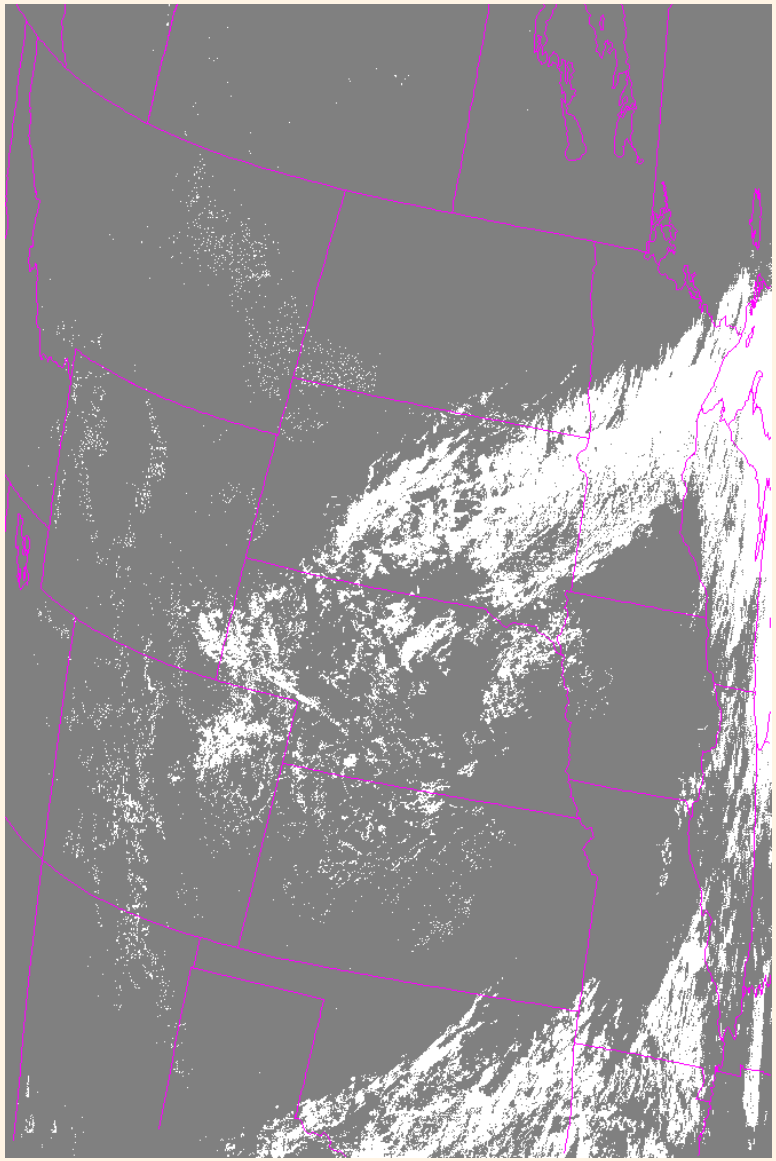


Band 31 (11.1µm)

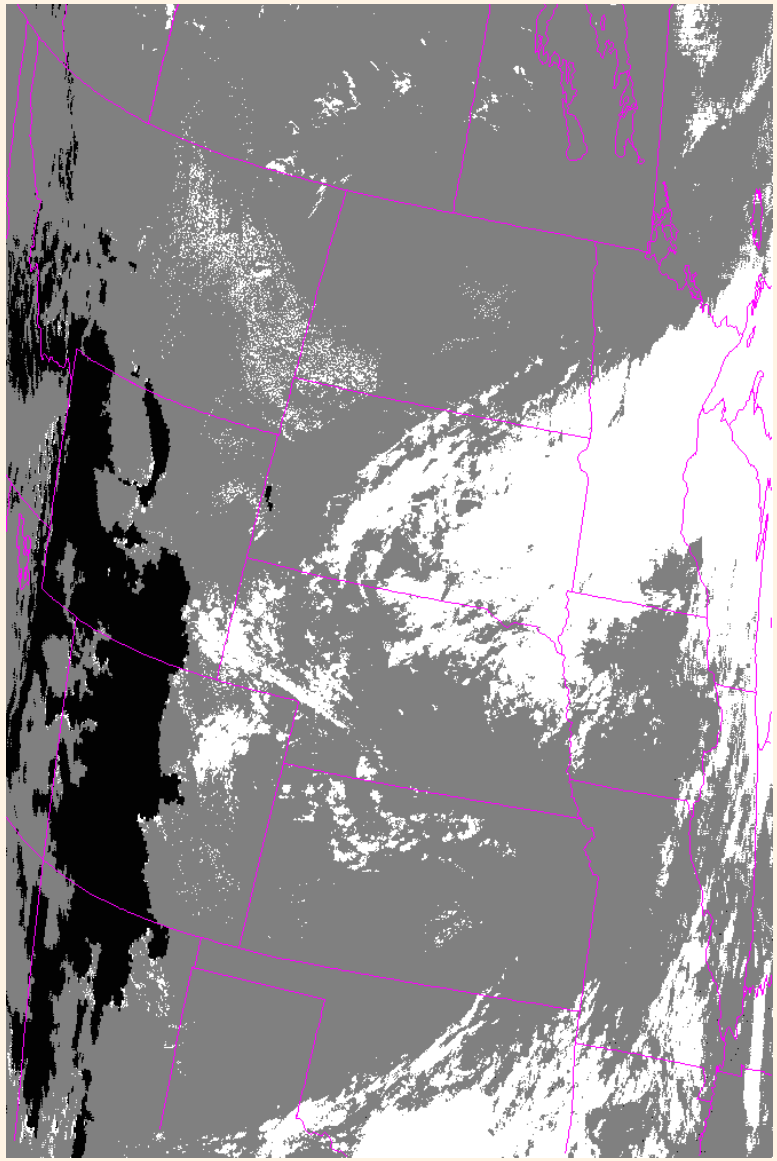


Band 26 (1.38µm)

MODIS 2006240 19:45 UTC (courtesy of R. Frey)

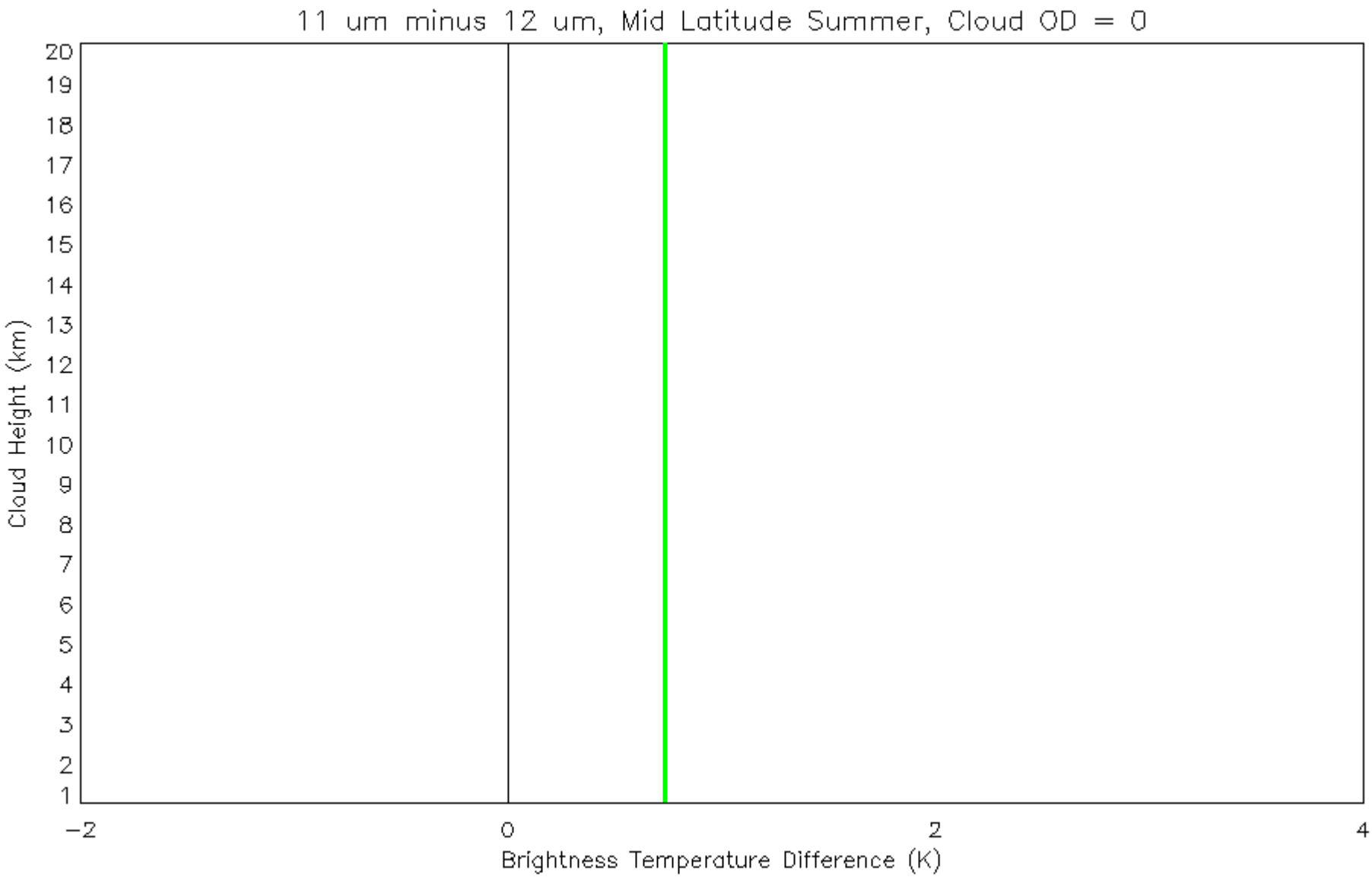


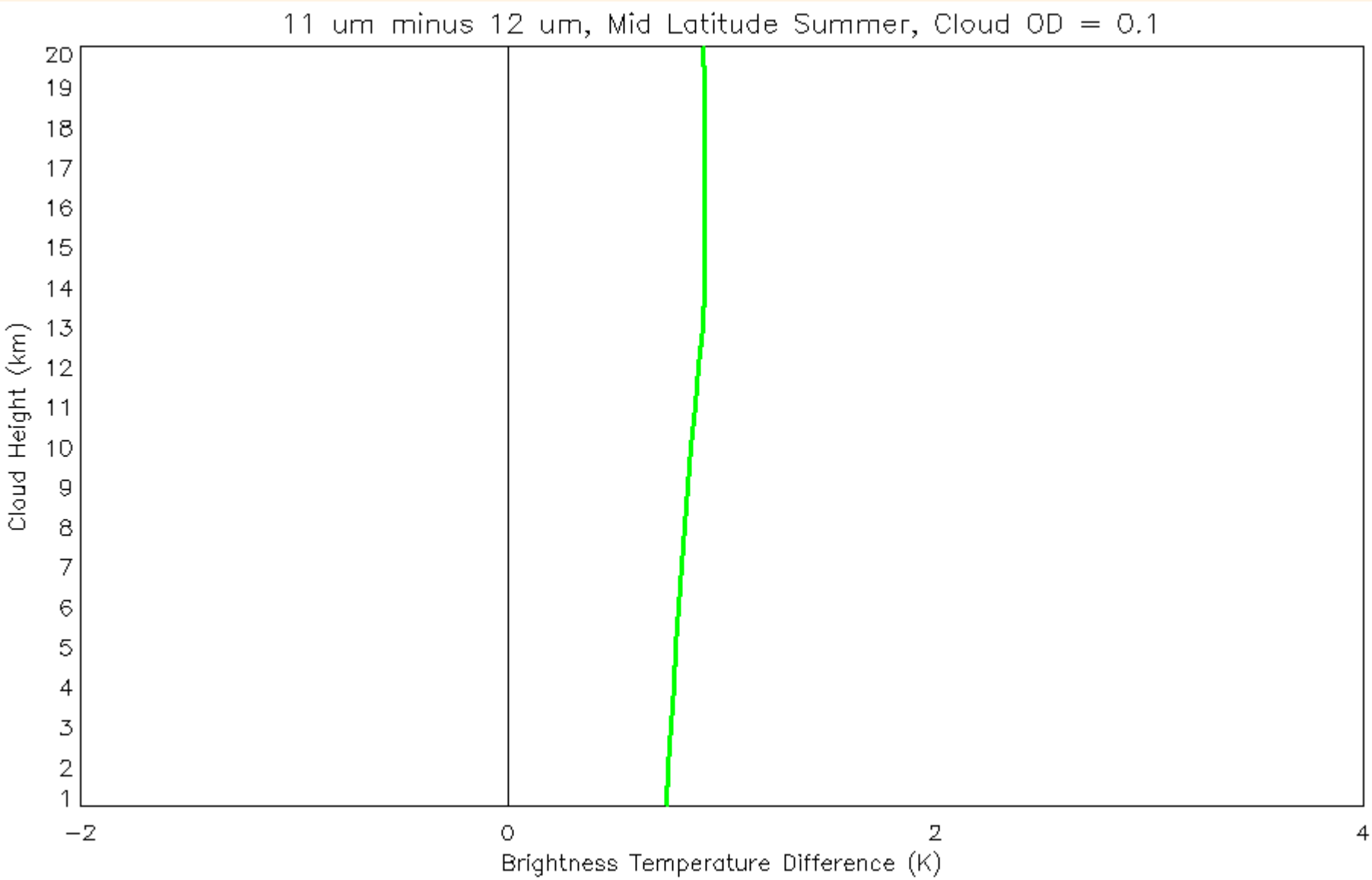
Split-window Test

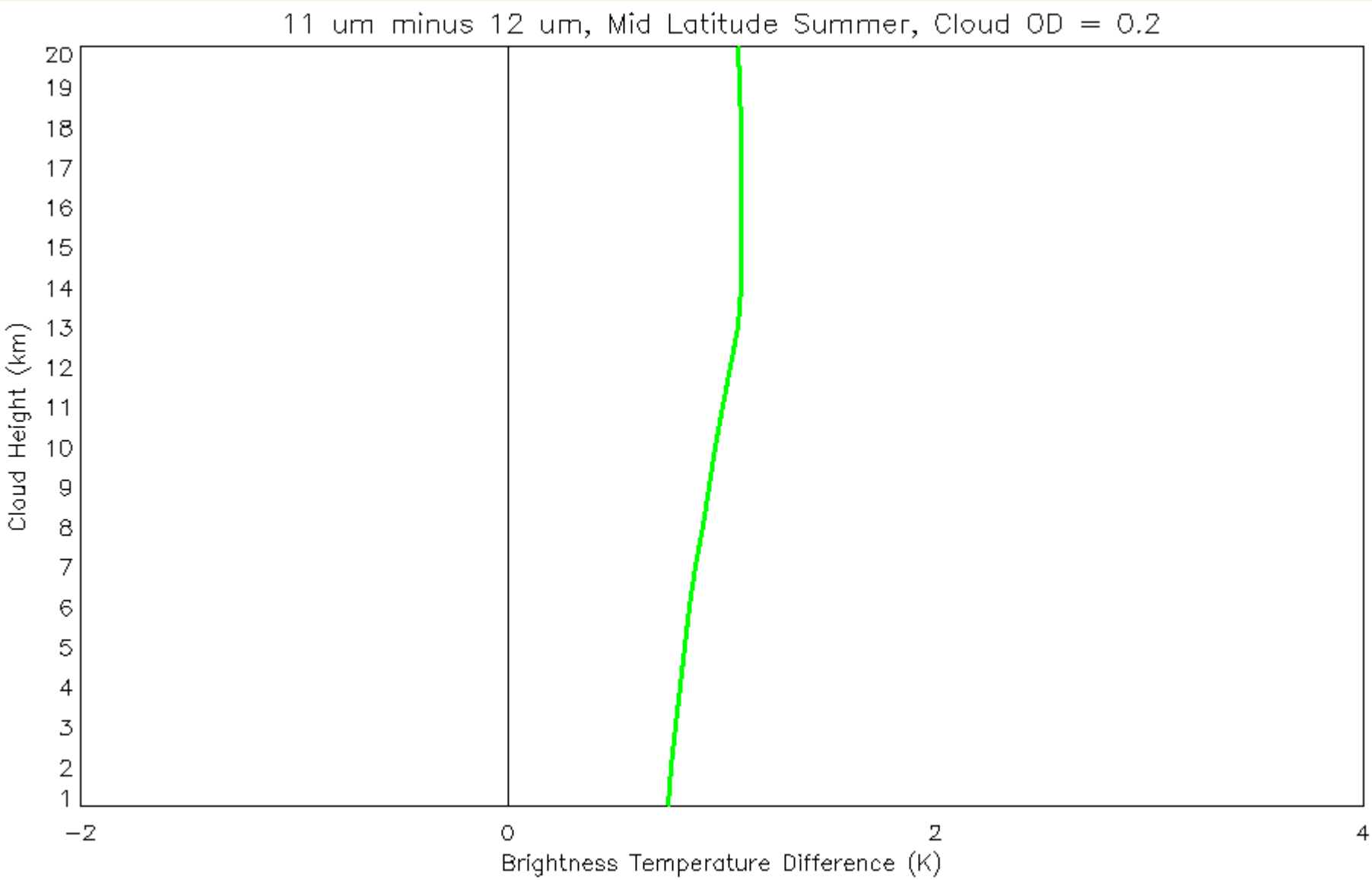


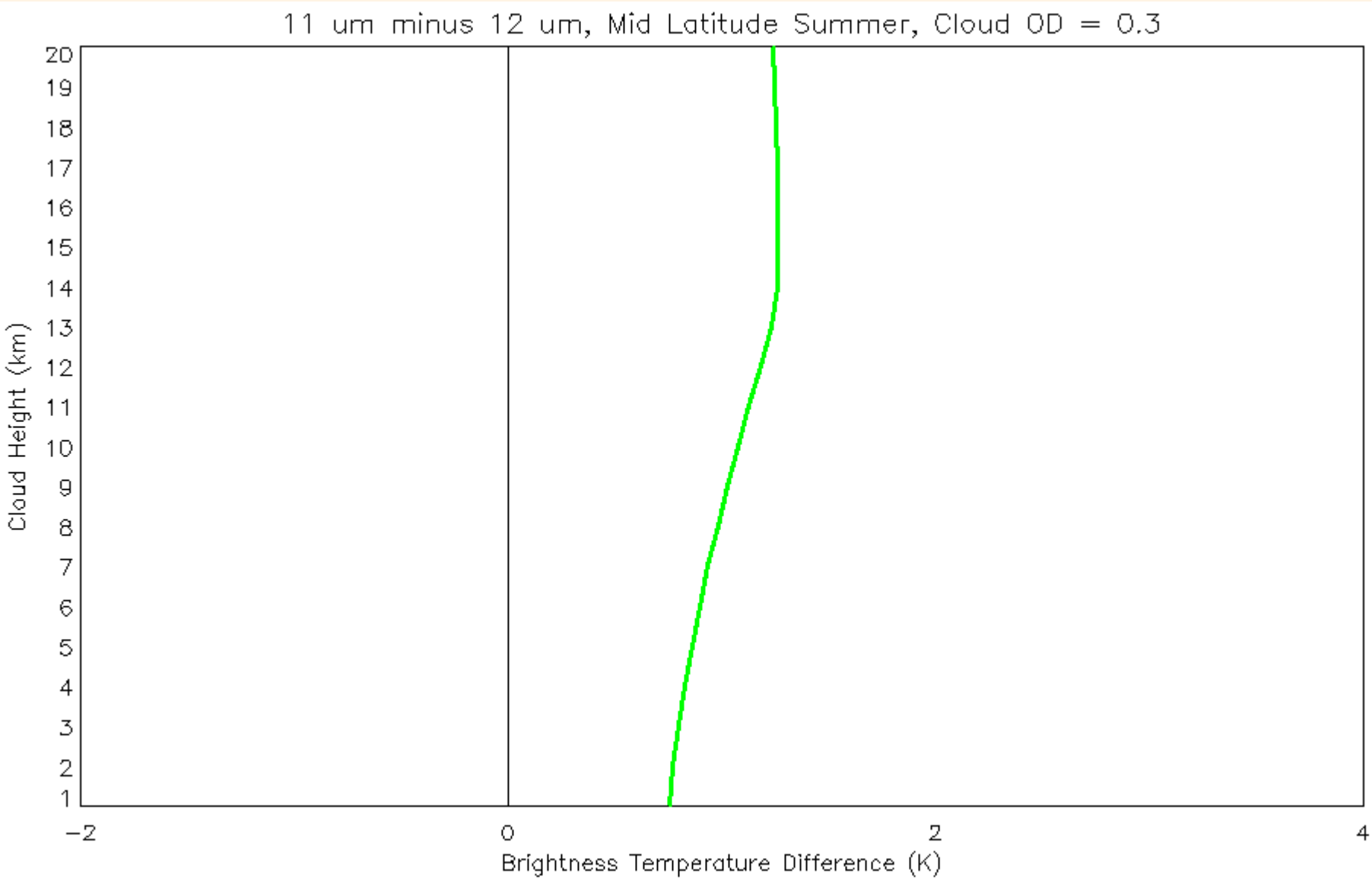
1.38 μm Ref. Test
(black means test not performed)

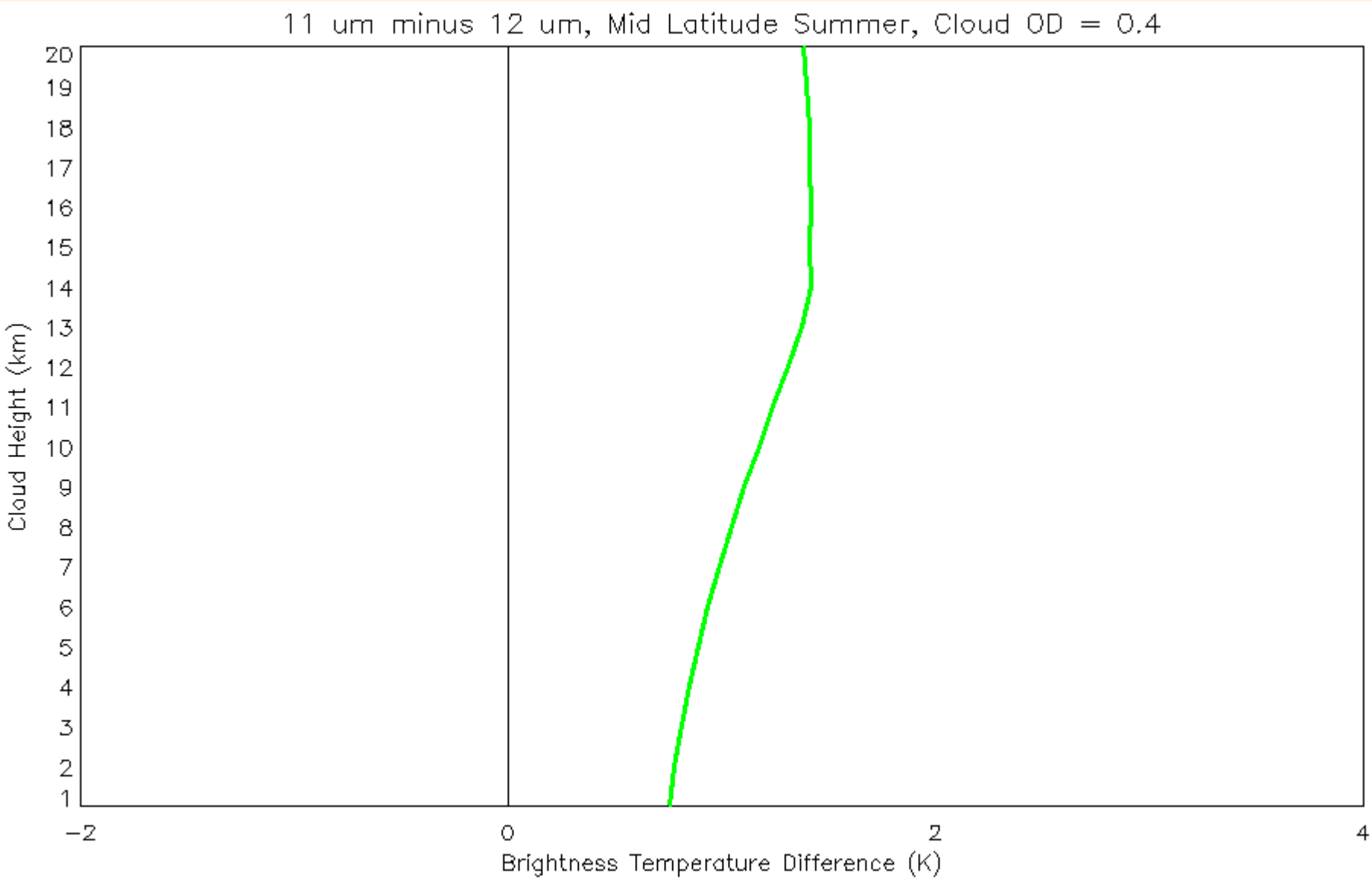
Simulations with standard atmospheres

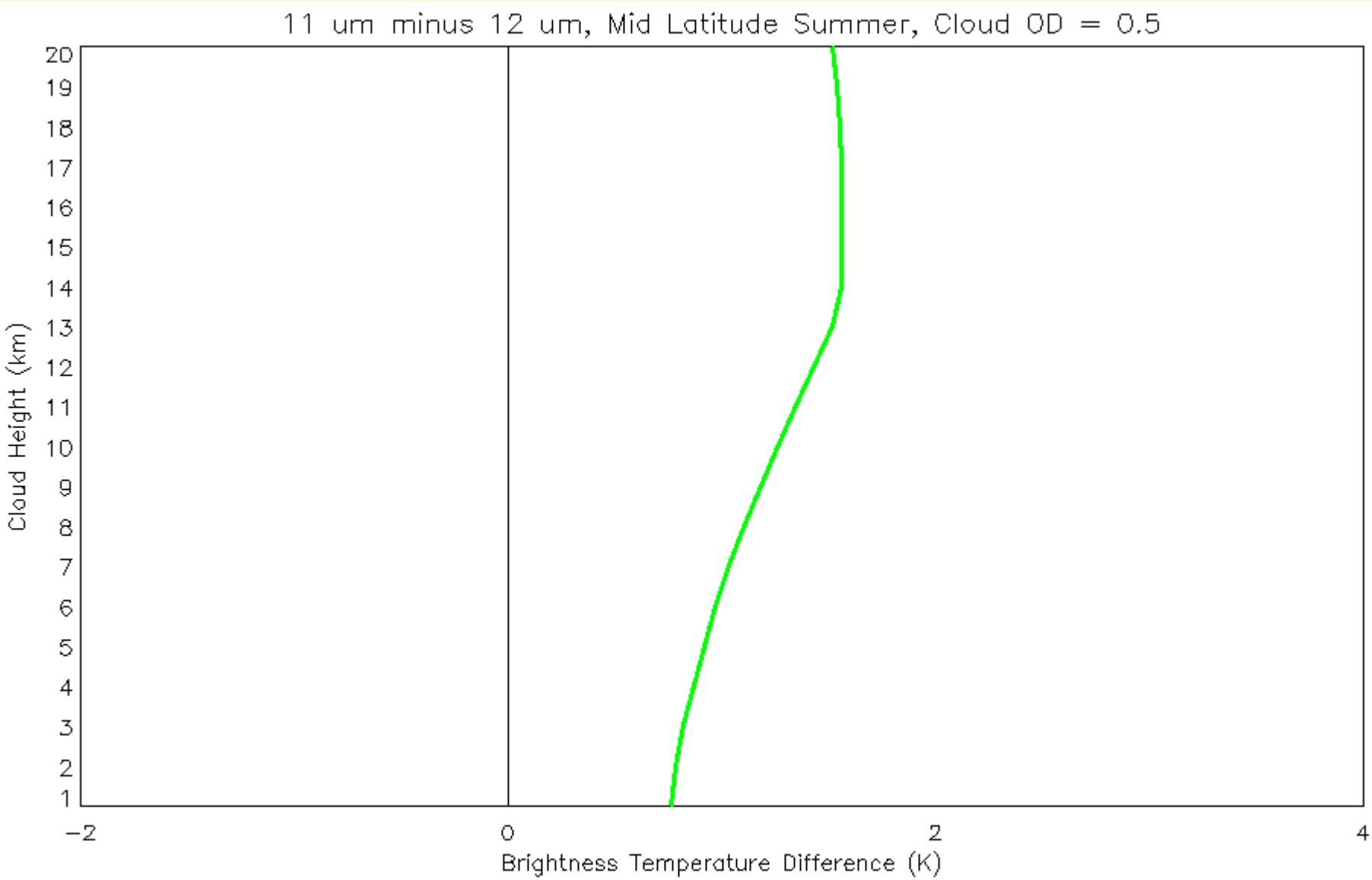

11 um minus 12 um, Mid Latitude Summer, Cloud OD = 0
Cloud Height (km)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
−2
0
2
4
Brightness Temperature Difference (K)

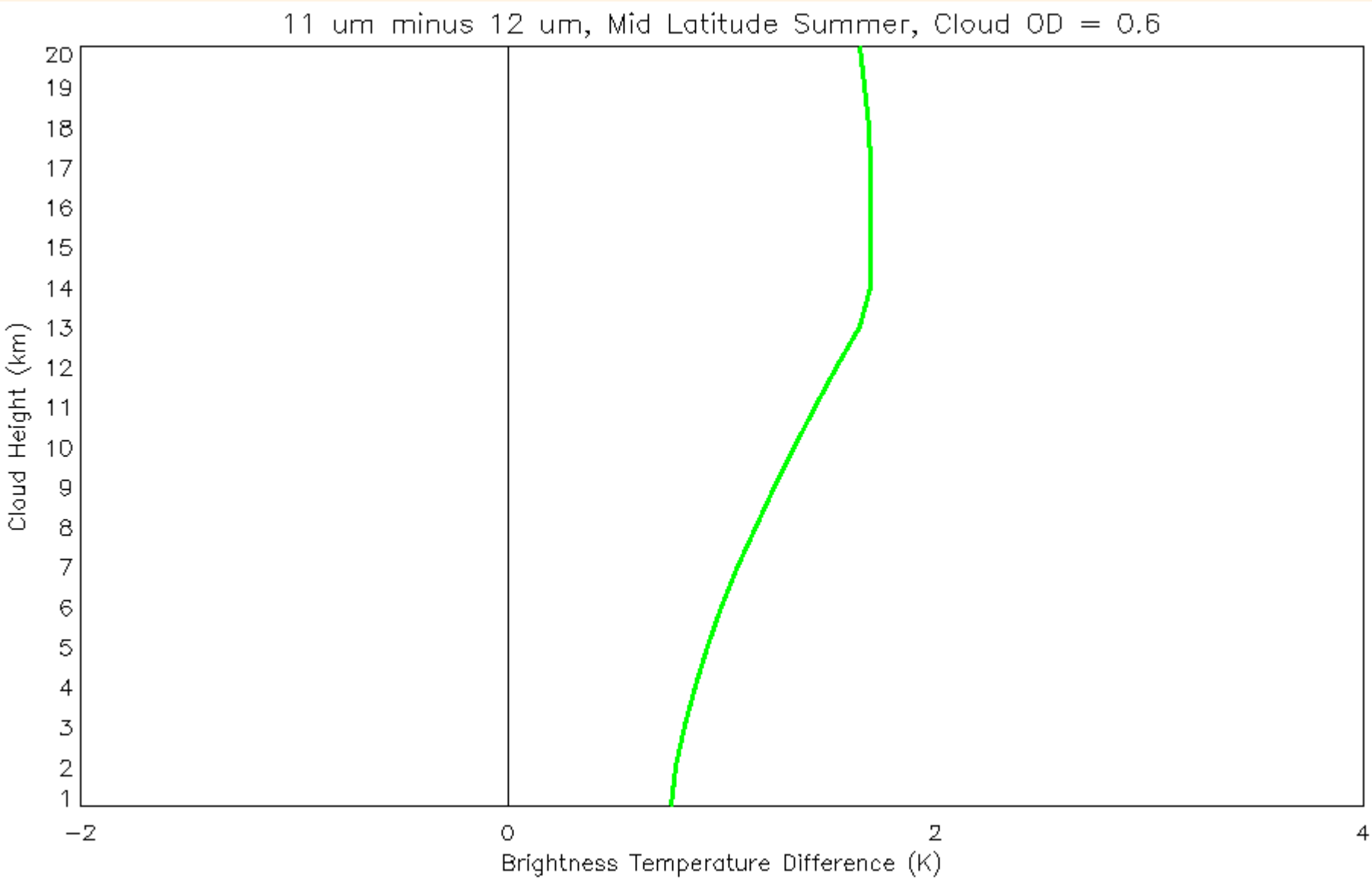

11 um minus 12 um, Mid Latitude Summer, Cloud OD = 0.1
Cloud Height (km)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
−2
0
2
4
Brightness Temperature Difference (K)

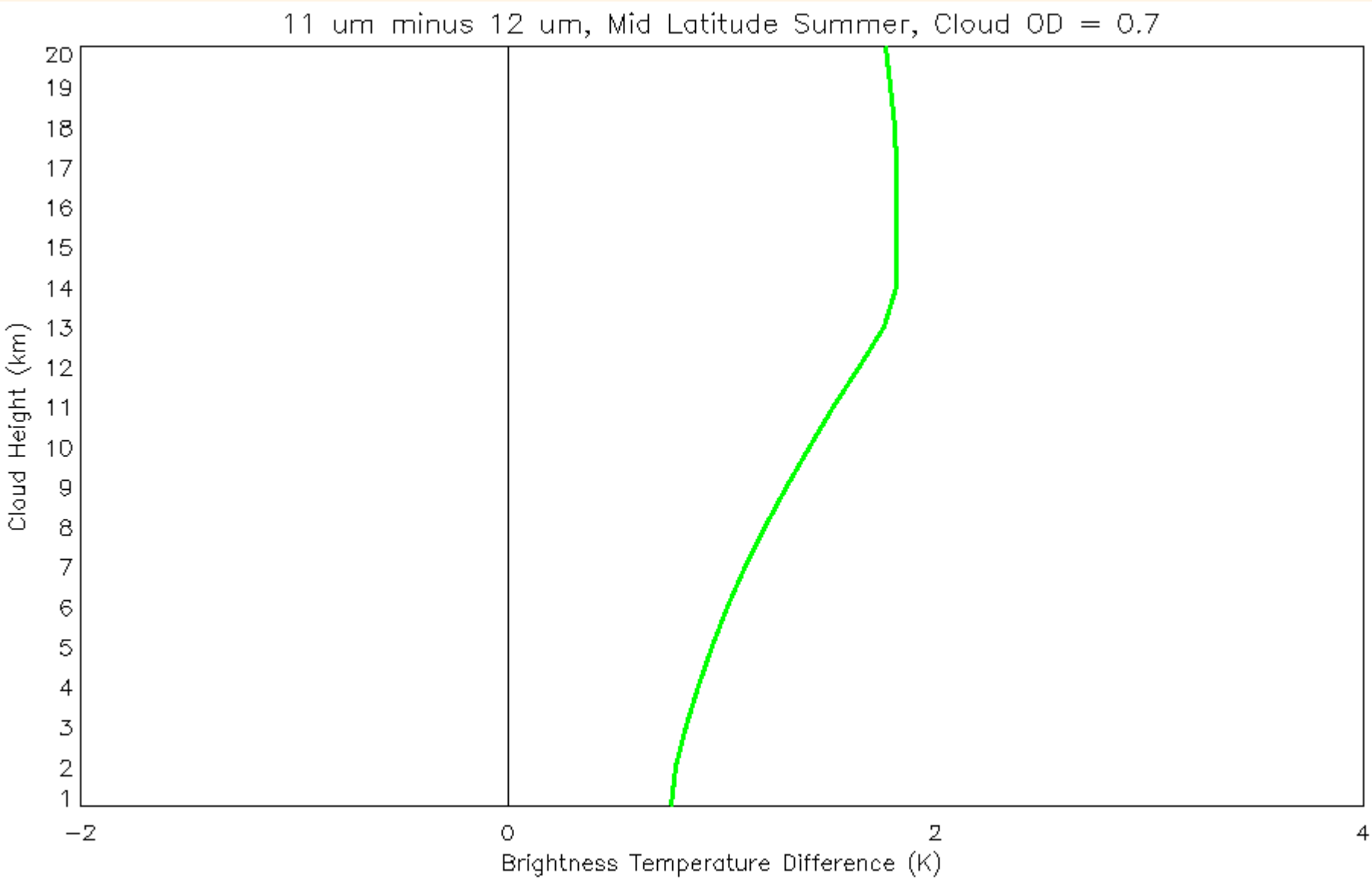

11 um minus 12 um, Mid Latitude Summer, Cloud OD = 0.2
Cloud Height (km)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
−2
0
2
4
Brightness Temperature Difference (K)

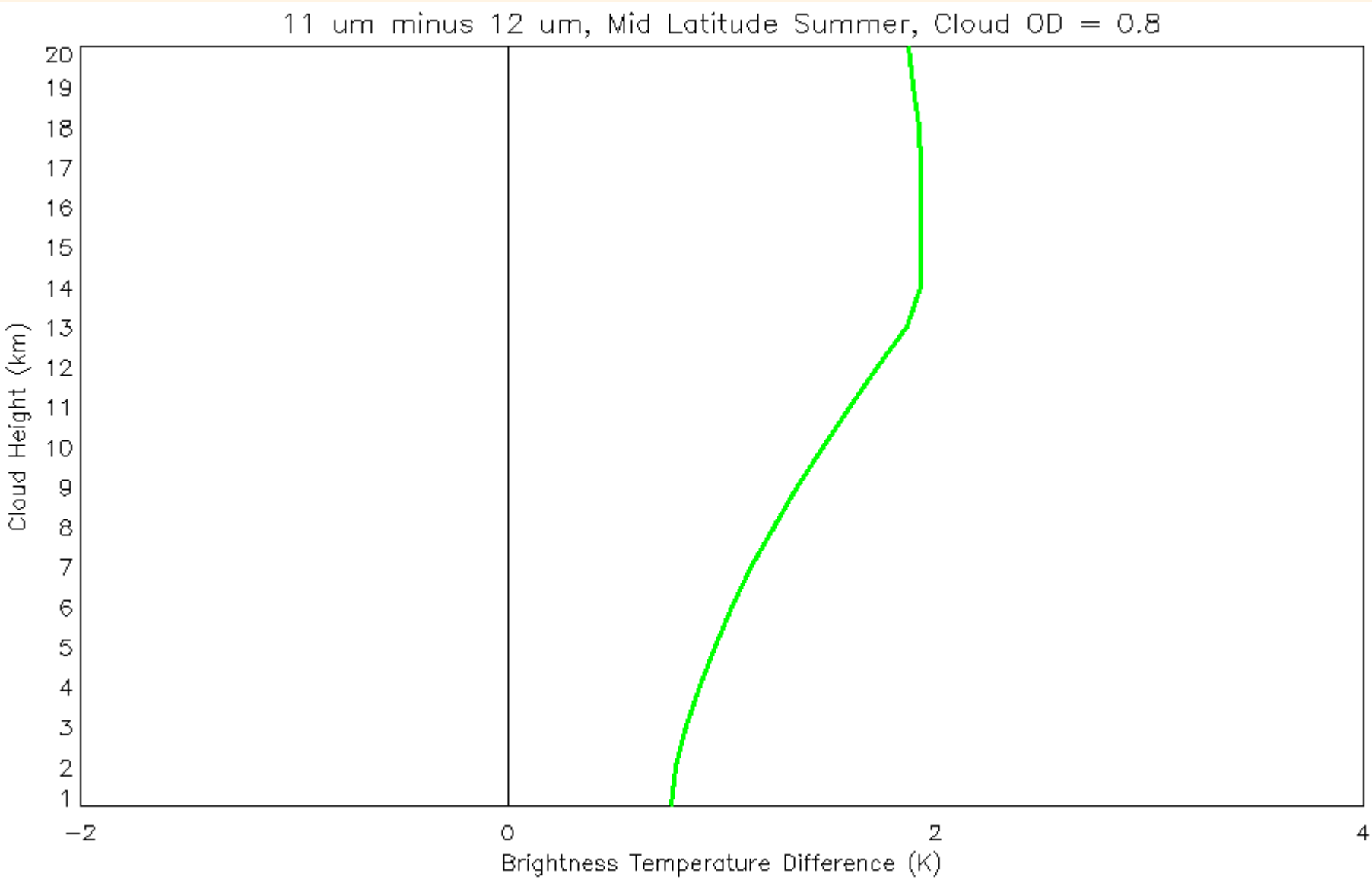

11 um minus 12 um, Mid Latitude Summer, Cloud OD = 0.3
Cloud Height (km)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
−2
0
2
4
Brightness Temperature Difference (K)

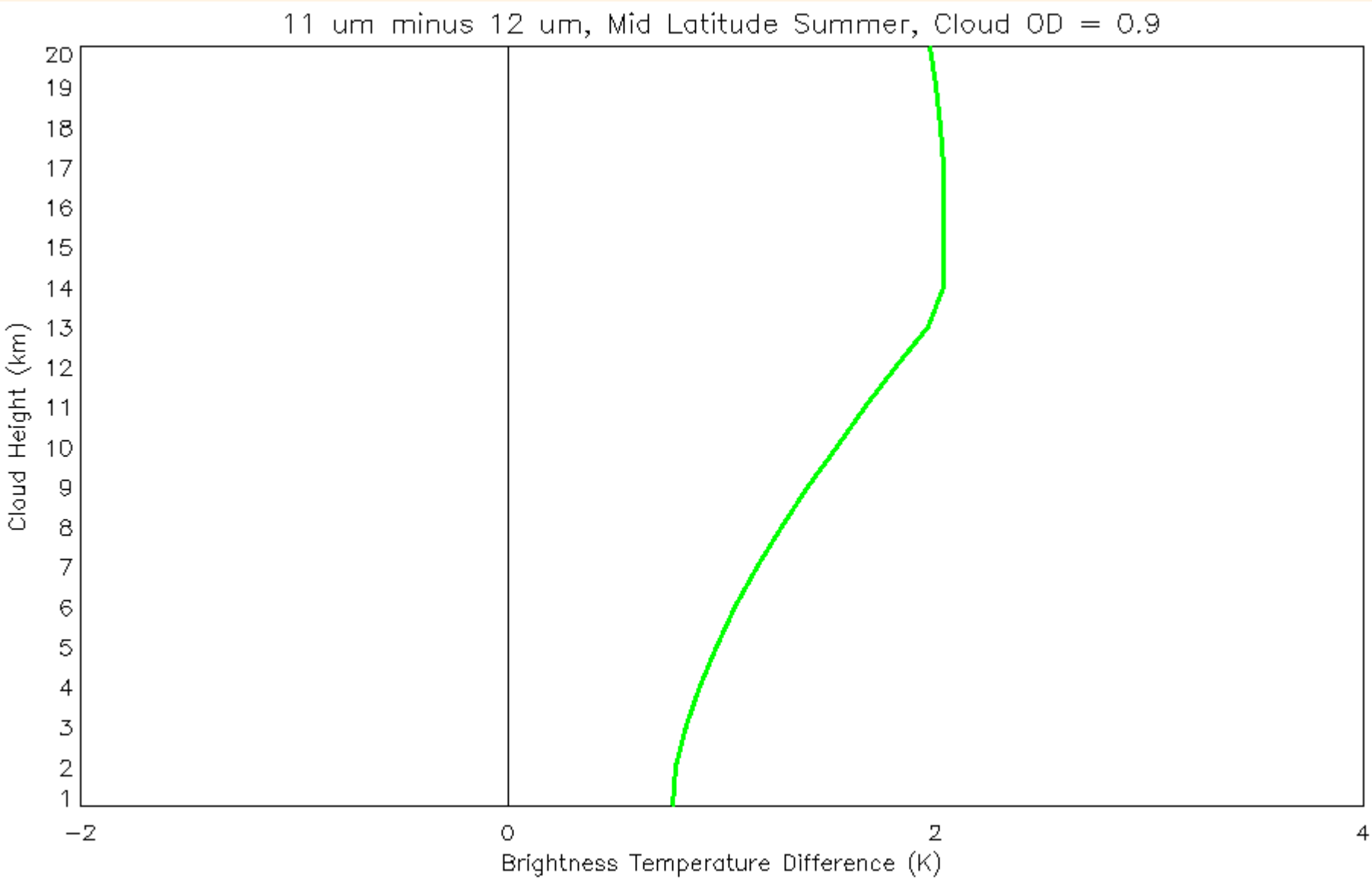

11 um minus 12 um, Mid Latitude Summer, Cloud OD = 0.4
Cloud Height (km)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
−2
0
2
4
Brightness Temperature Difference (K)

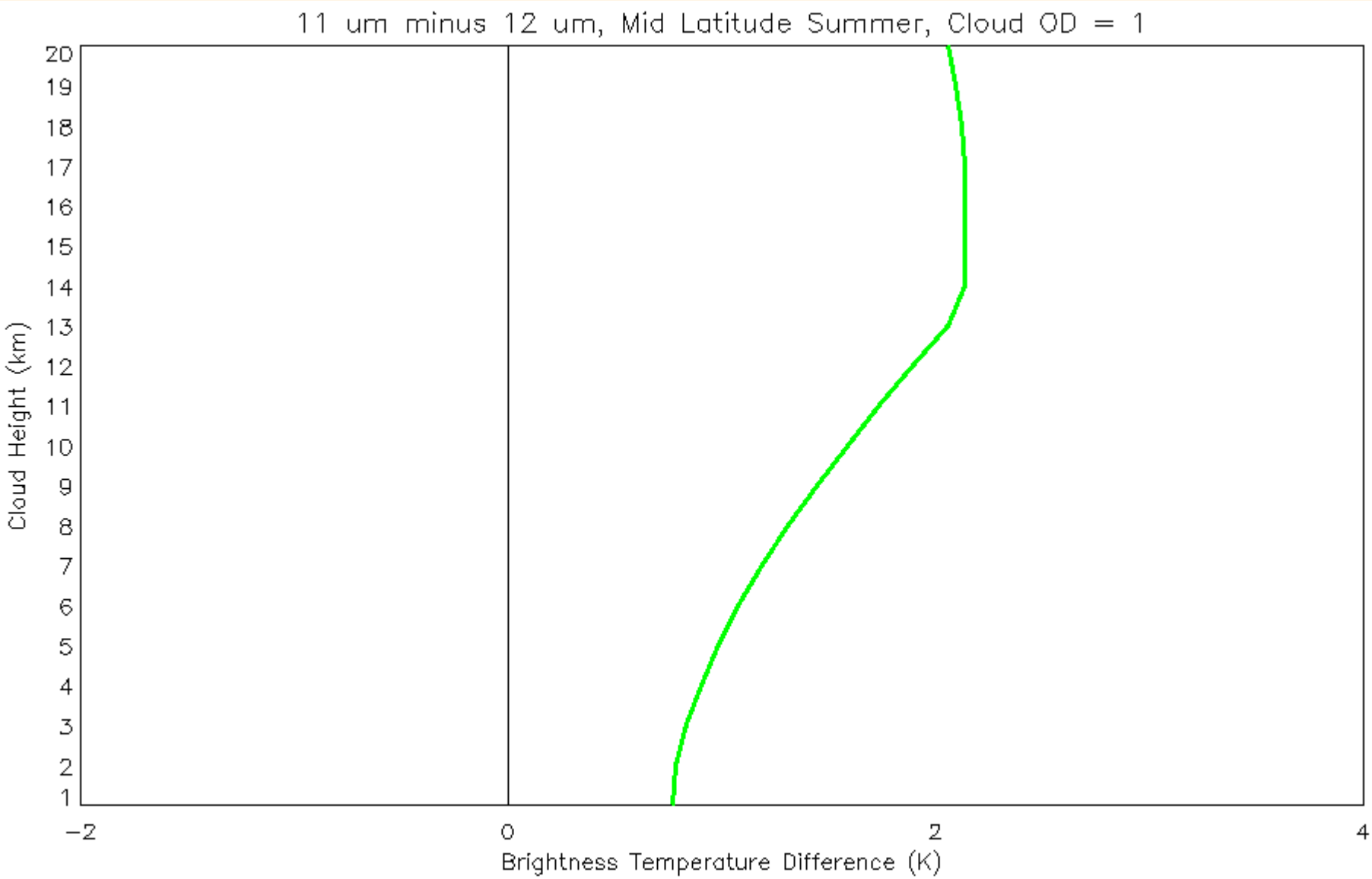

11 um minus 12 um, Mid Latitude Summer, Cloud OD = 0.5
Cloud Height (km)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
−2
0
2
4
Brightness Temperature Difference (K)

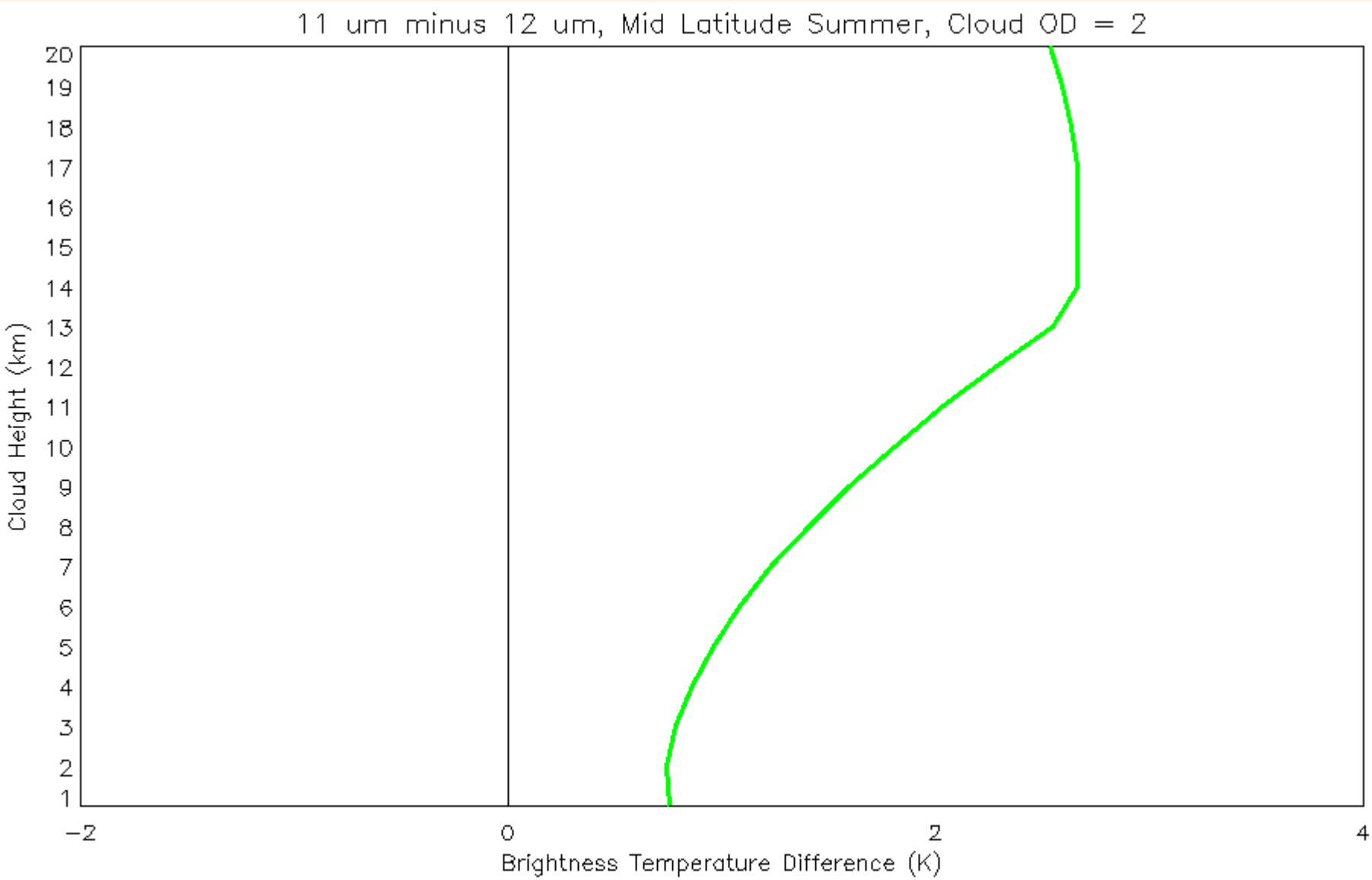

11 um minus 12 um, Mid Latitude Summer, Cloud OD = 0.6
Cloud Height (km)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
−2
0
2
4
Brightness Temperature Difference (K)

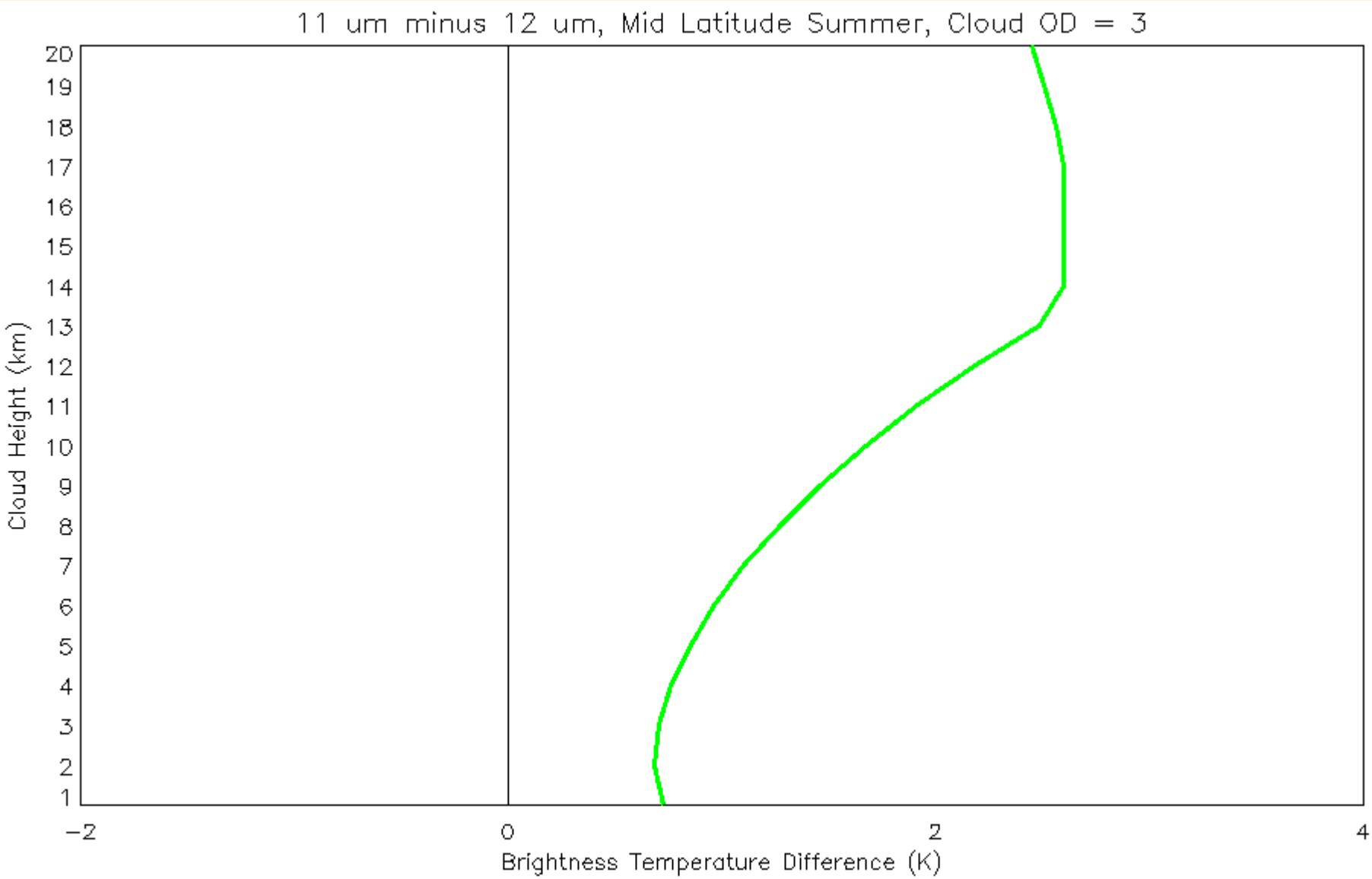

11 um minus 12 um, Mid Latitude Summer, Cloud OD = 0.7
Cloud Height (km)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
−2
0
2
4
Brightness Temperature Difference (K)

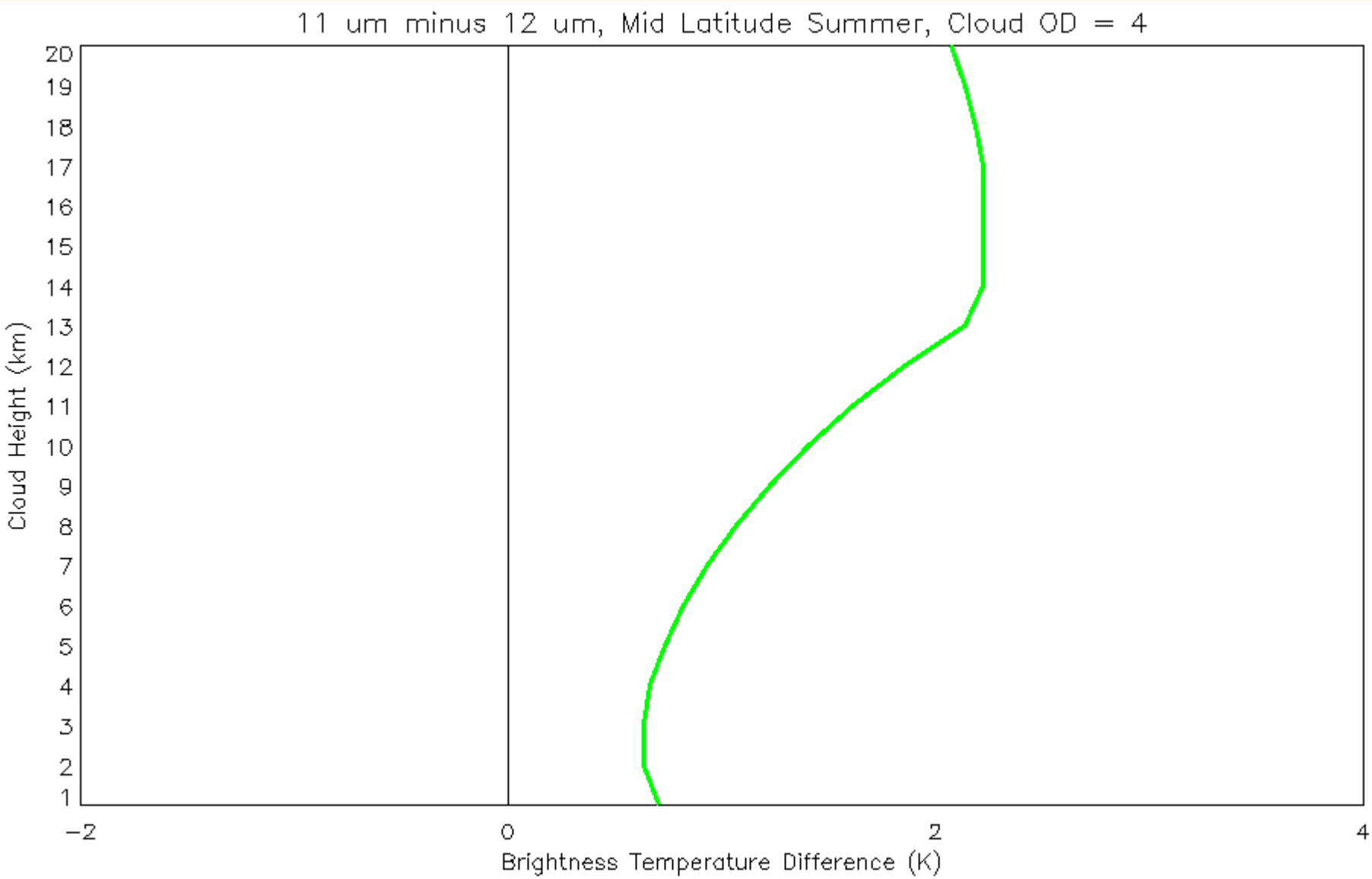

11 um minus 12 um, Mid Latitude Summer, Cloud OD = 0.8
Cloud Height (km)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
−2
0
2
4
Brightness Temperature Difference (K)

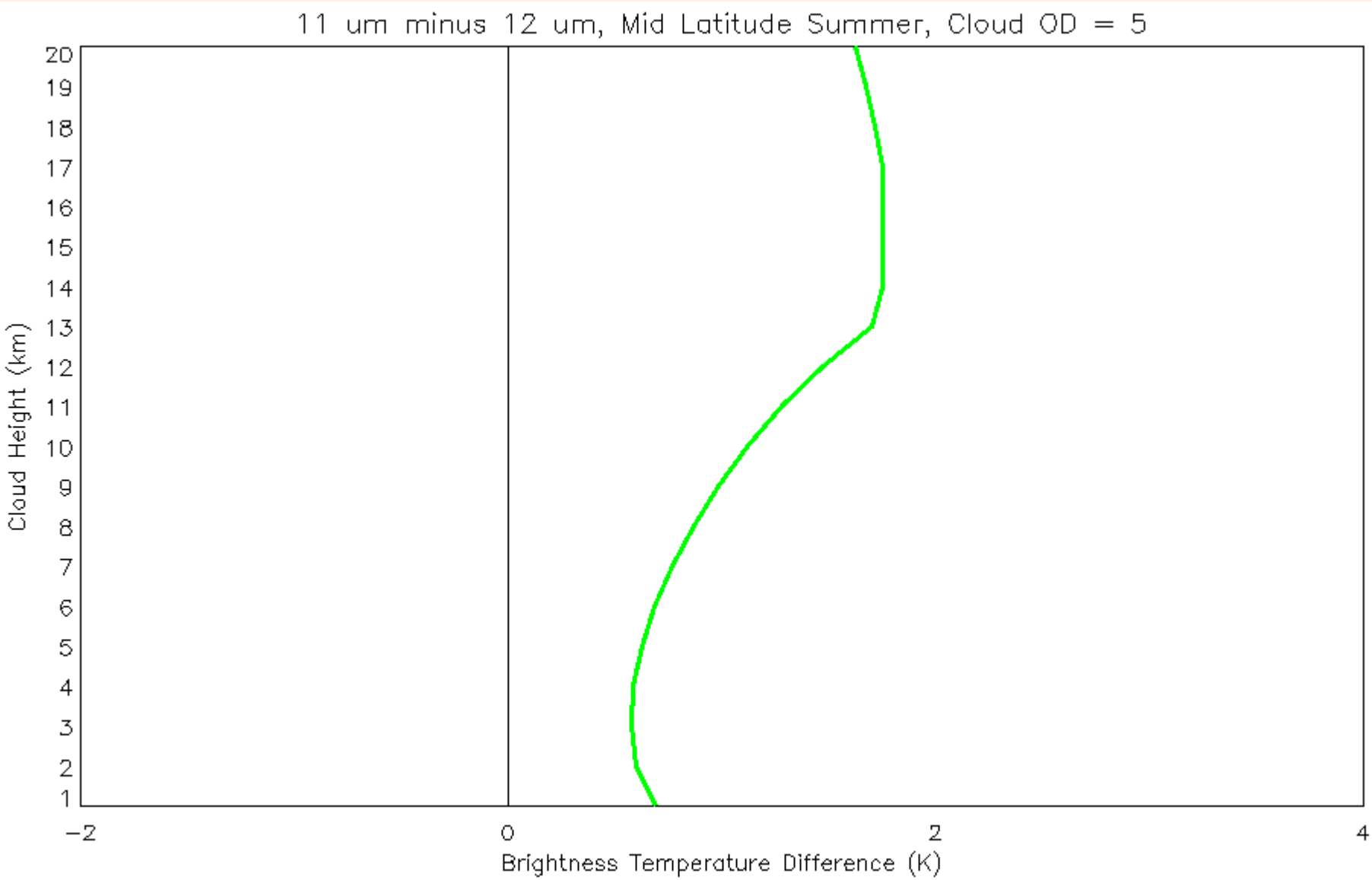

11 um minus 12 um, Mid Latitude Summer, Cloud OD = 0.9
Cloud Height (km)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
−2
0
2
4
Brightness Temperature Difference (K)

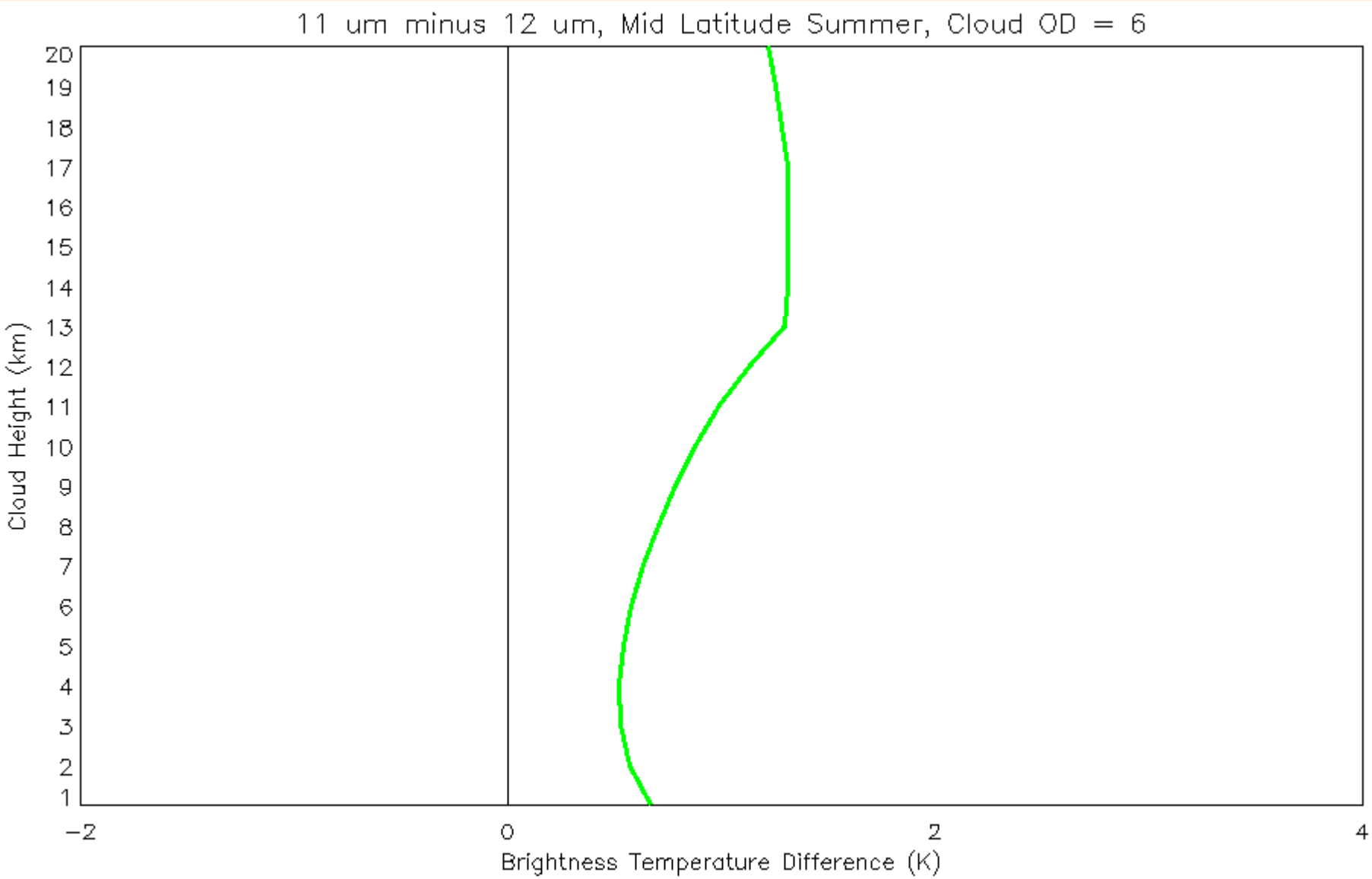

11 um minus 12 um, Mid Latitude Summer, Cloud OD = 1
Cloud Height (km)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
−2
0
2
4
Brightness Temperature Difference (K)

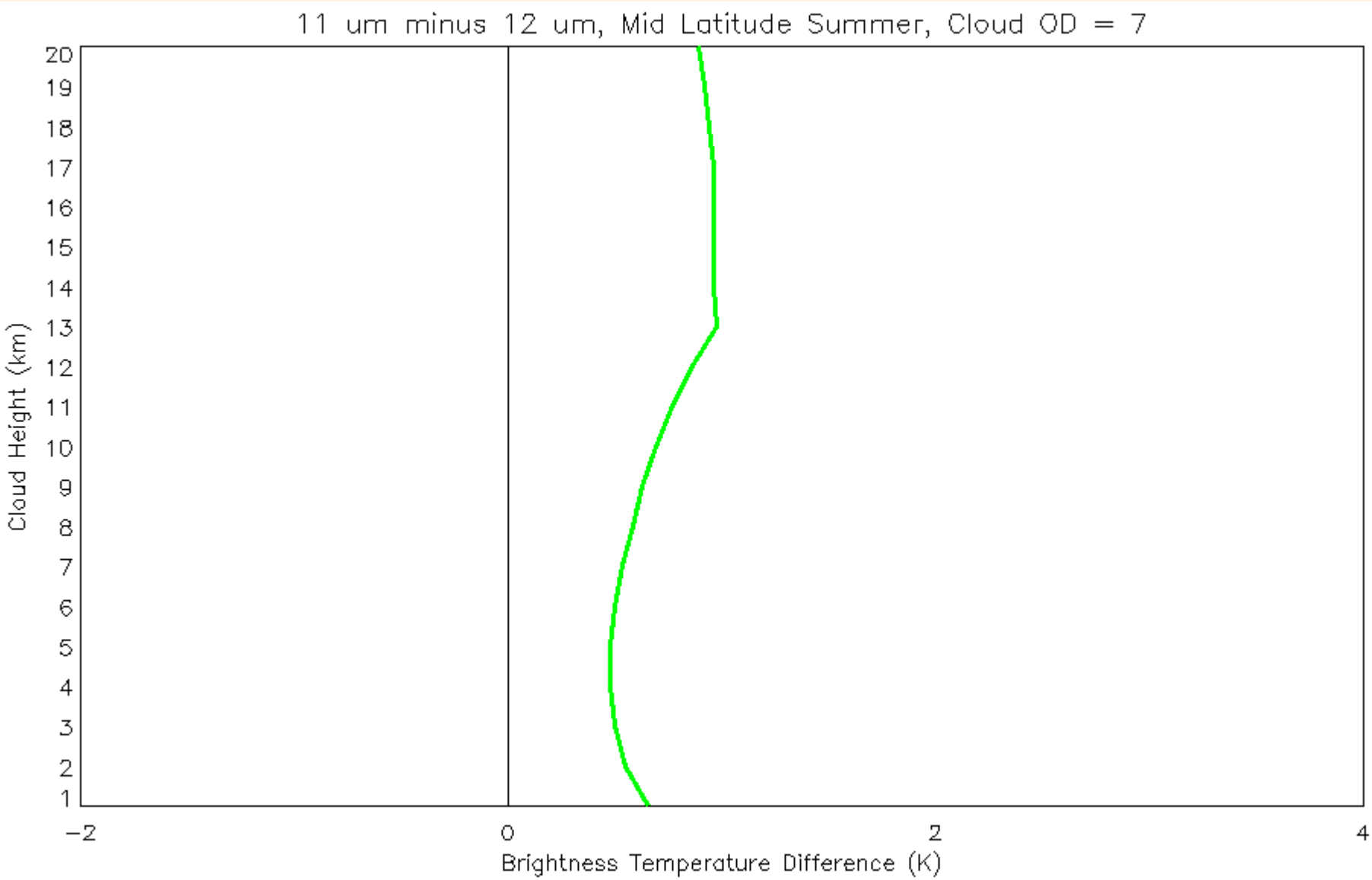

11 um minus 12 um, Mid Latitude Summer, Cloud OD = 2
Cloud Height (km)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
−2
0
2
4
Brightness Temperature Difference (K)

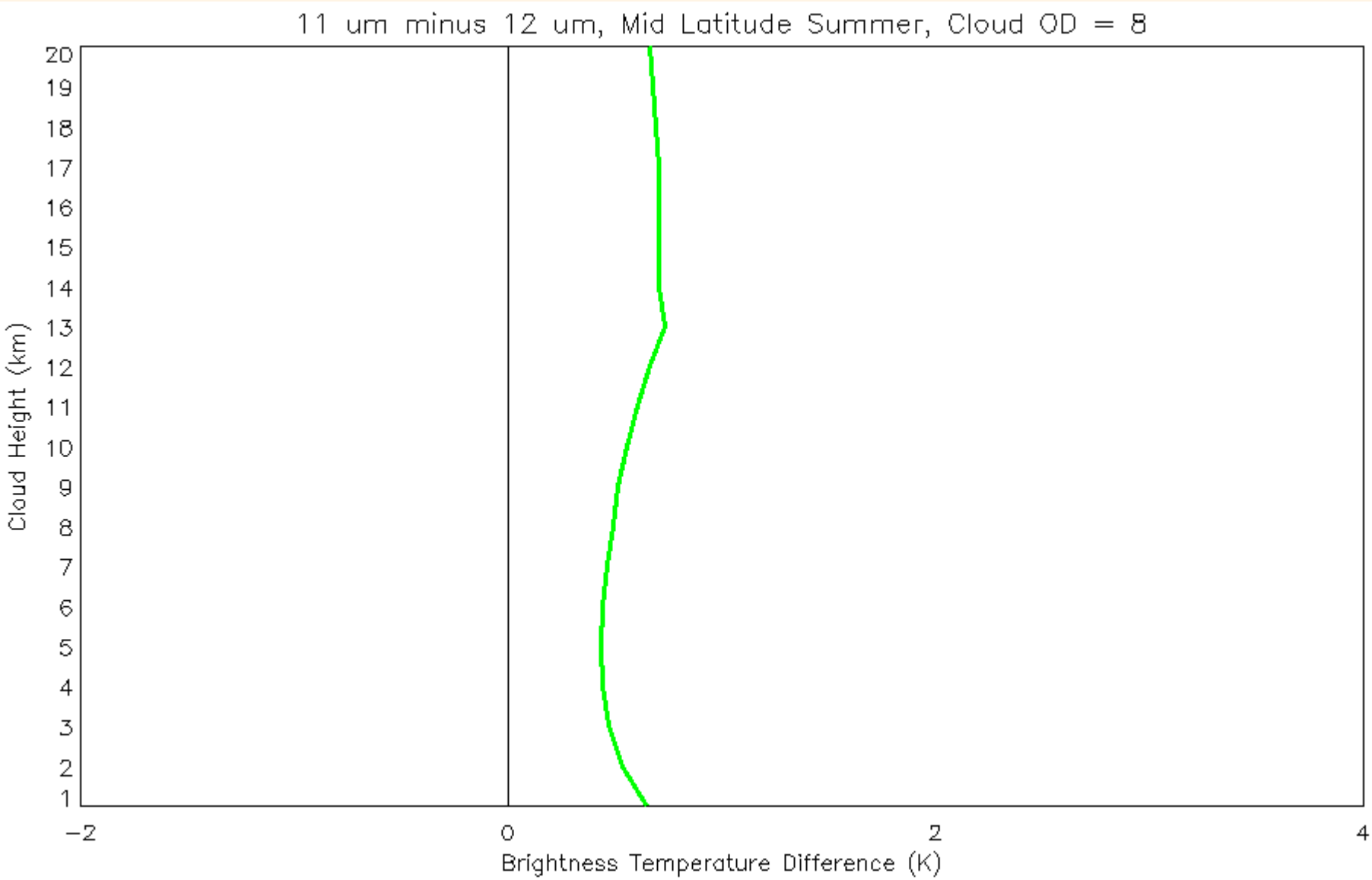

11 um minus 12 um, Mid Latitude Summer, Cloud OD = 3
Cloud Height (km)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
−2
0
2
4
Brightness Temperature Difference (K)

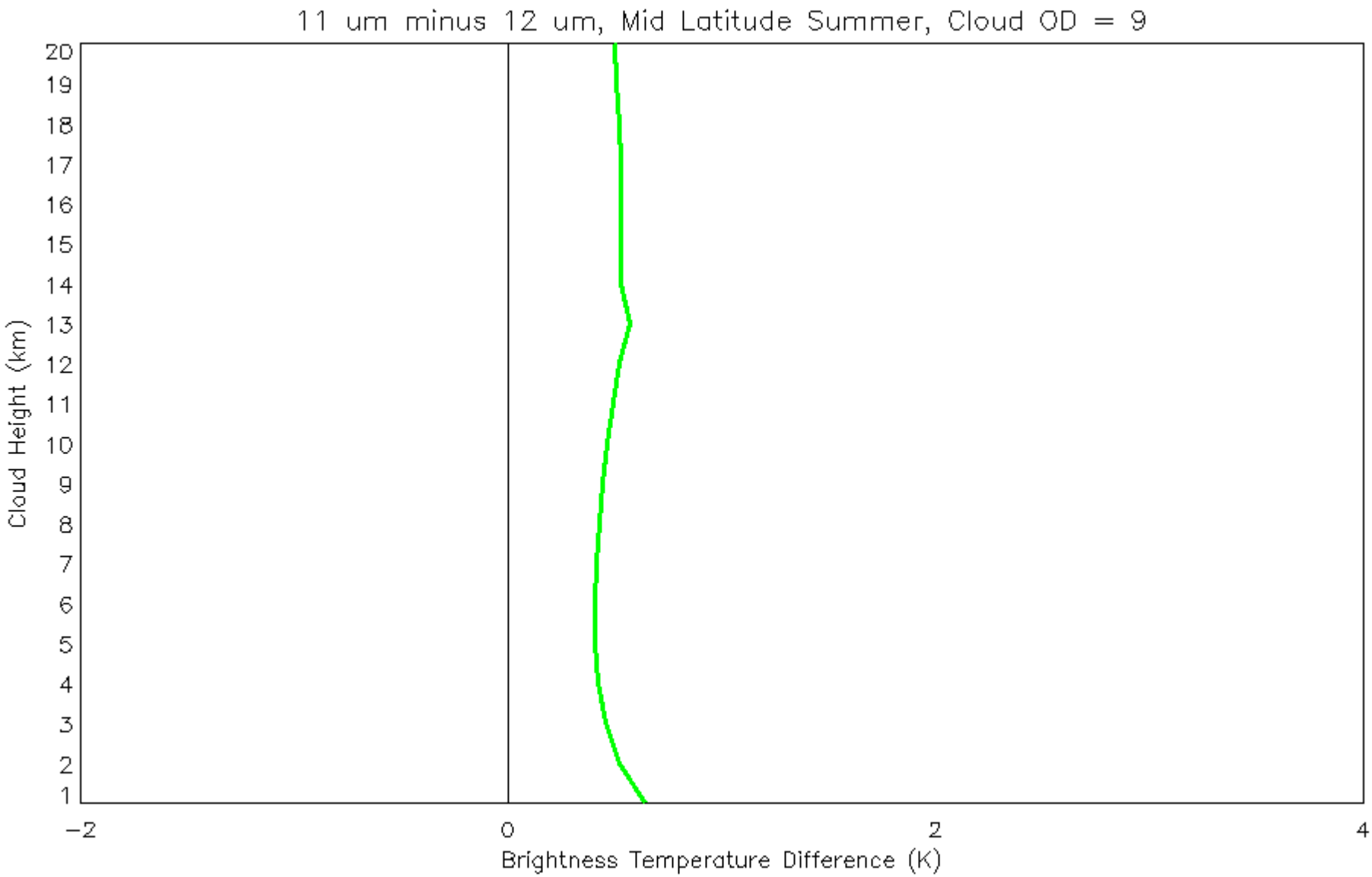

11 um minus 12 um, Mid Latitude Summer, Cloud OD = 4
Cloud Height (km)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
−2
0
2
4
Brightness Temperature Difference (K)


11 um minus 12 um, Mid Latitude Summer, Cloud OD = 5
Cloud Height (km)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
−2
0
2
4
Brightness Temperature Difference (K)


11 um minus 12 um, Mid Latitude Summer, Cloud OD = 6
Cloud Height (km)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
−2
0
2
4
Brightness Temperature Difference (K)


11 um minus 12 um, Mid Latitude Summer, Cloud OD = 7
Cloud Height (km)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
−2
0
2
4
Brightness Temperature Difference (K)


11 um minus 12 um, Mid Latitude Summer, Cloud OD = 8
Cloud Height (km)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
−2
0
2
4
Brightness Temperature Difference (K)

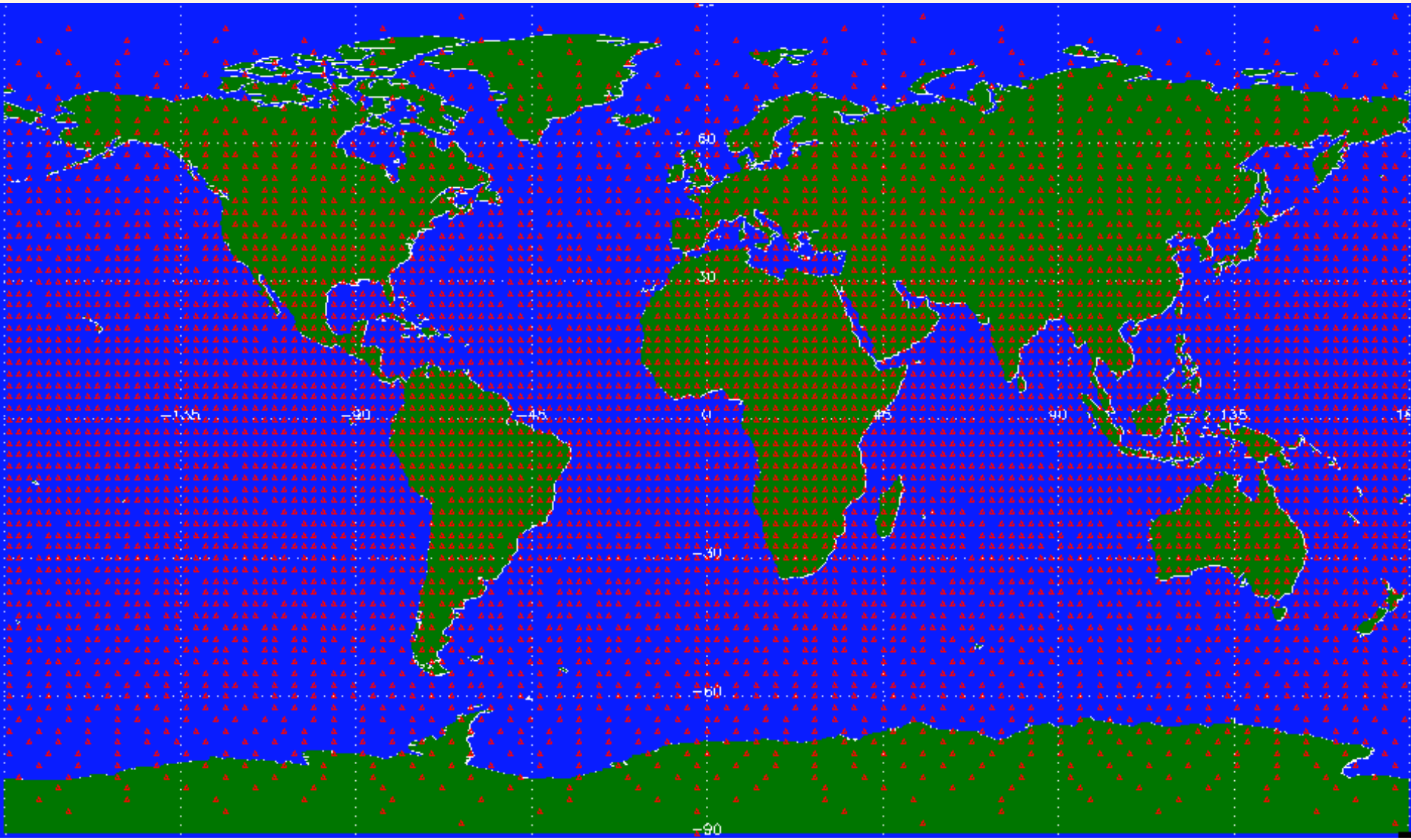

11 um minus 12 um, Mid Latitude Summer, Cloud OD = 9
Cloud Height (km)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
−2
0
2
4
Brightness Temperature Difference (K)

Simulations with re-analysis atmospheres (ECMWF)

Thresholding the Split Window

- The difference in Brightness Temperature between 11 μm and 12 μm is calculated for gridded ECMWF data.
  - ECMWF is on 2.5 degree longitude by 2.5 degree latitude grid.
  - All data taken at 00 Z on January 15, 2002.
  - Total of 10512 different profiles, each with information on pressure, height, temperature, ozone, and water vapor.
  - Converted to an equal area grid, so that polar regions are not unfairly emphasized; 6454 profiles remained for analysis.

Selected profiles shown by triangles

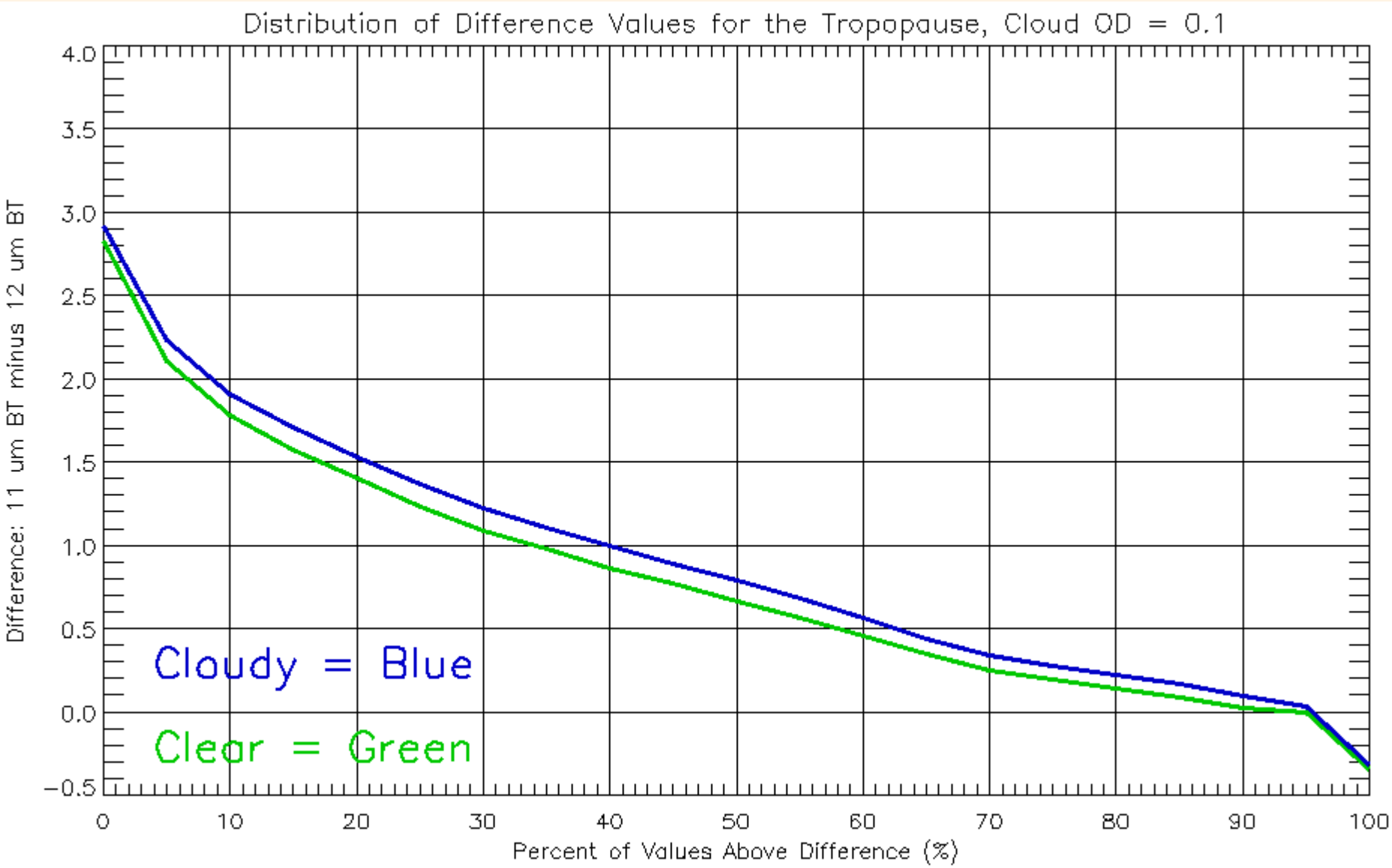


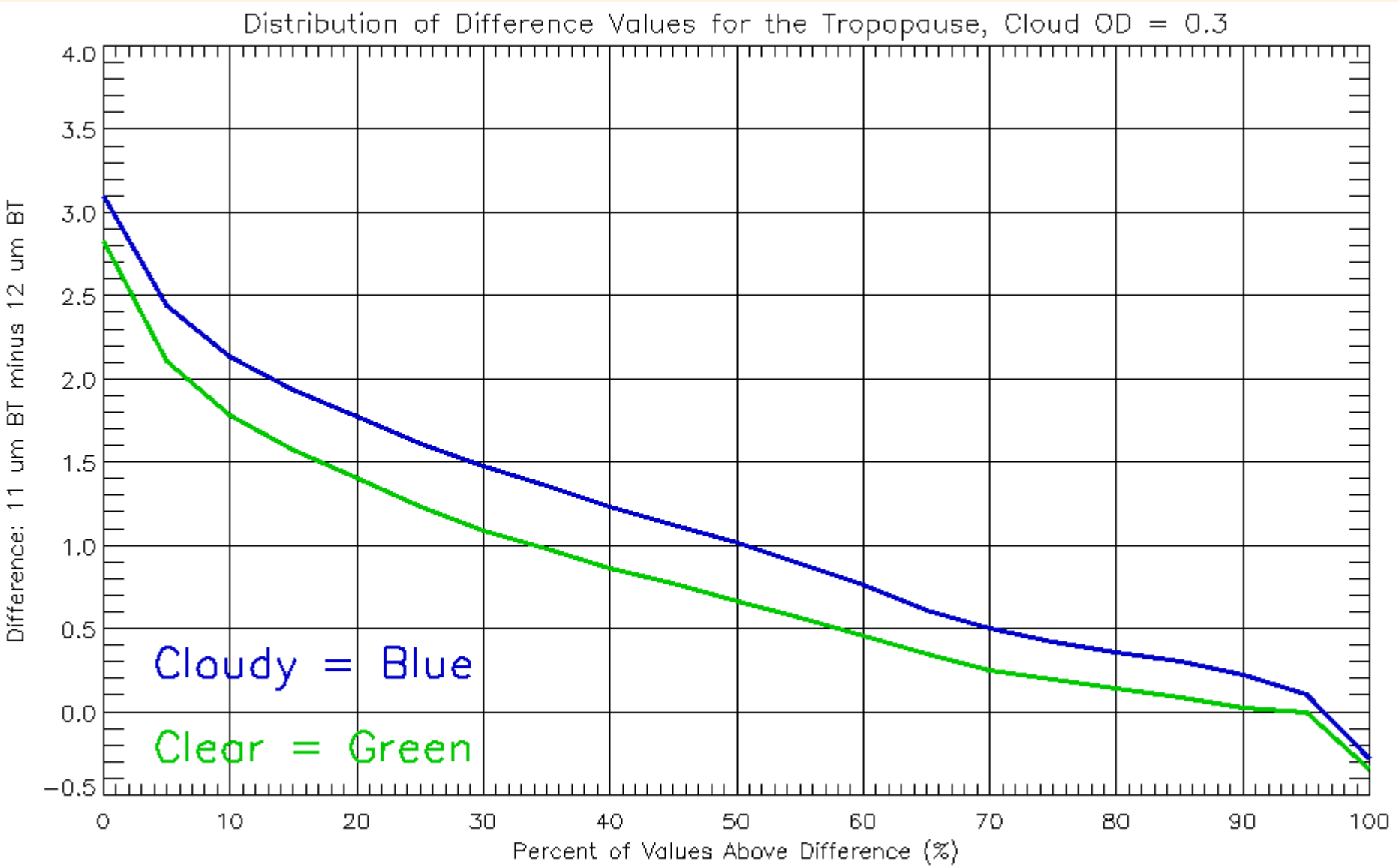
Fewer Triangles occur near the poles

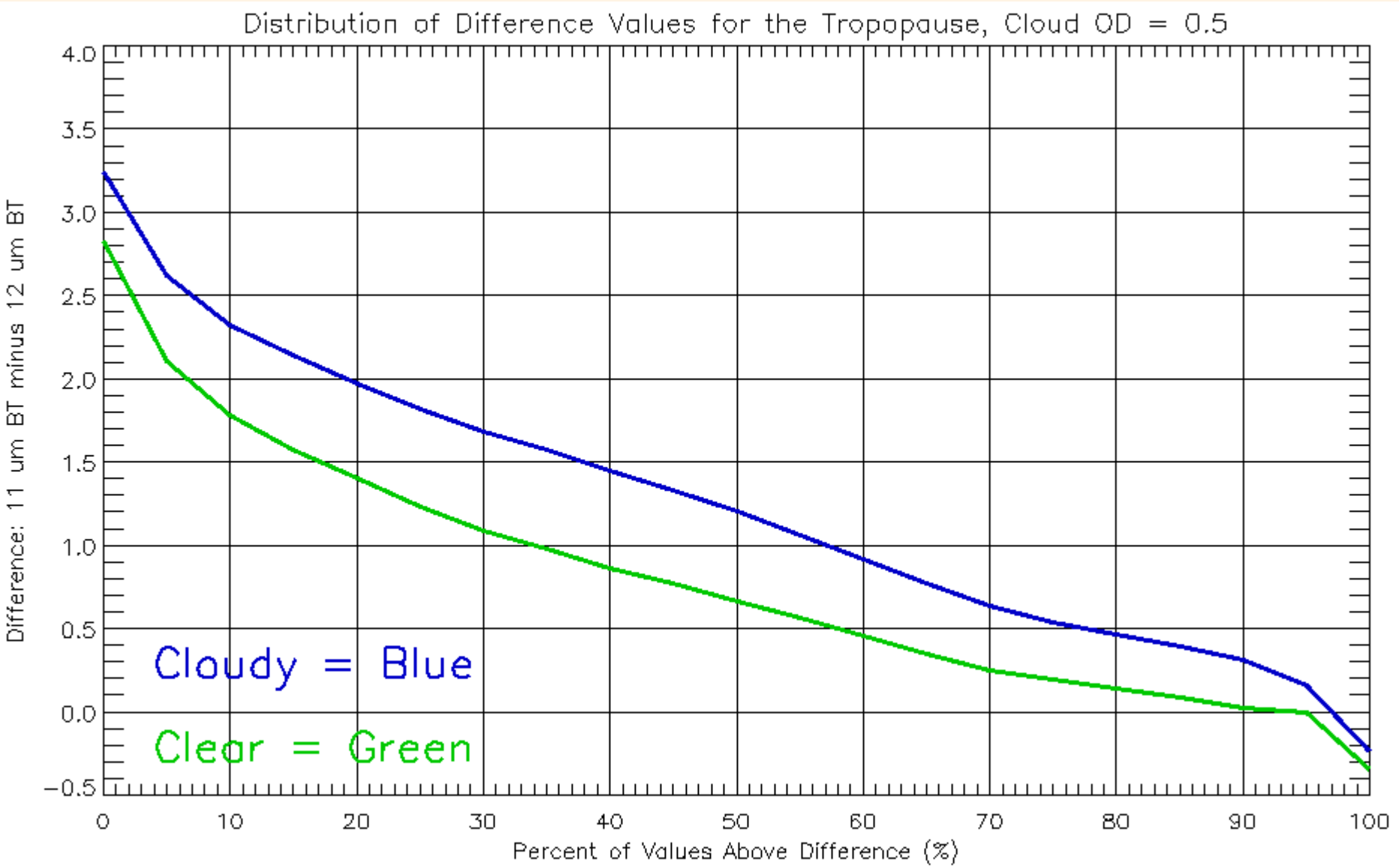
Simulations with clouds at tropopause

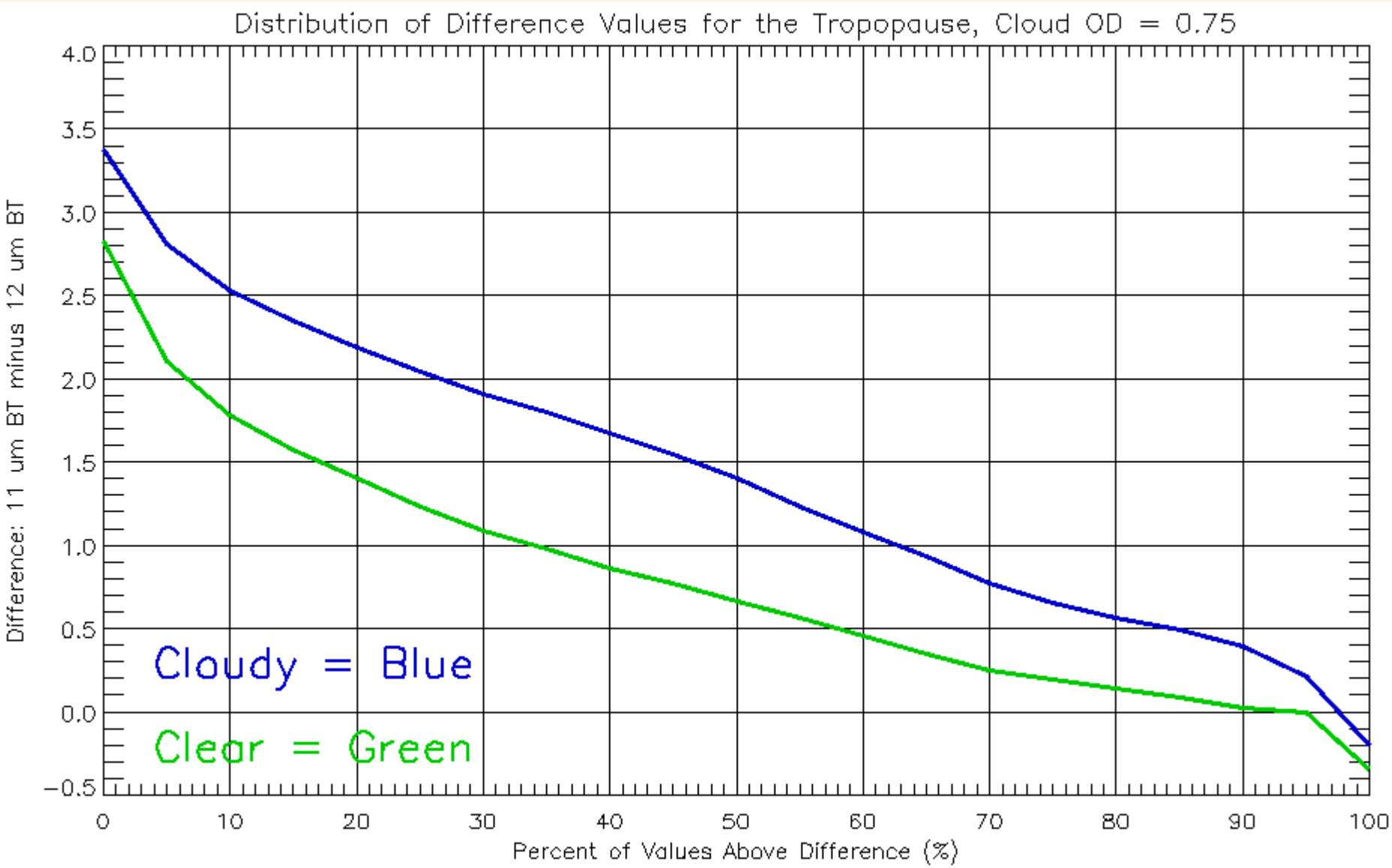
- A cloud of a given optical depth (0.1, 0.3, 0.5, 0.75, 1, 2, 3, 4) was placed in each of 6454 profiles at the calculated tropopause level (where the lapse rate dropped below 2 K/km)

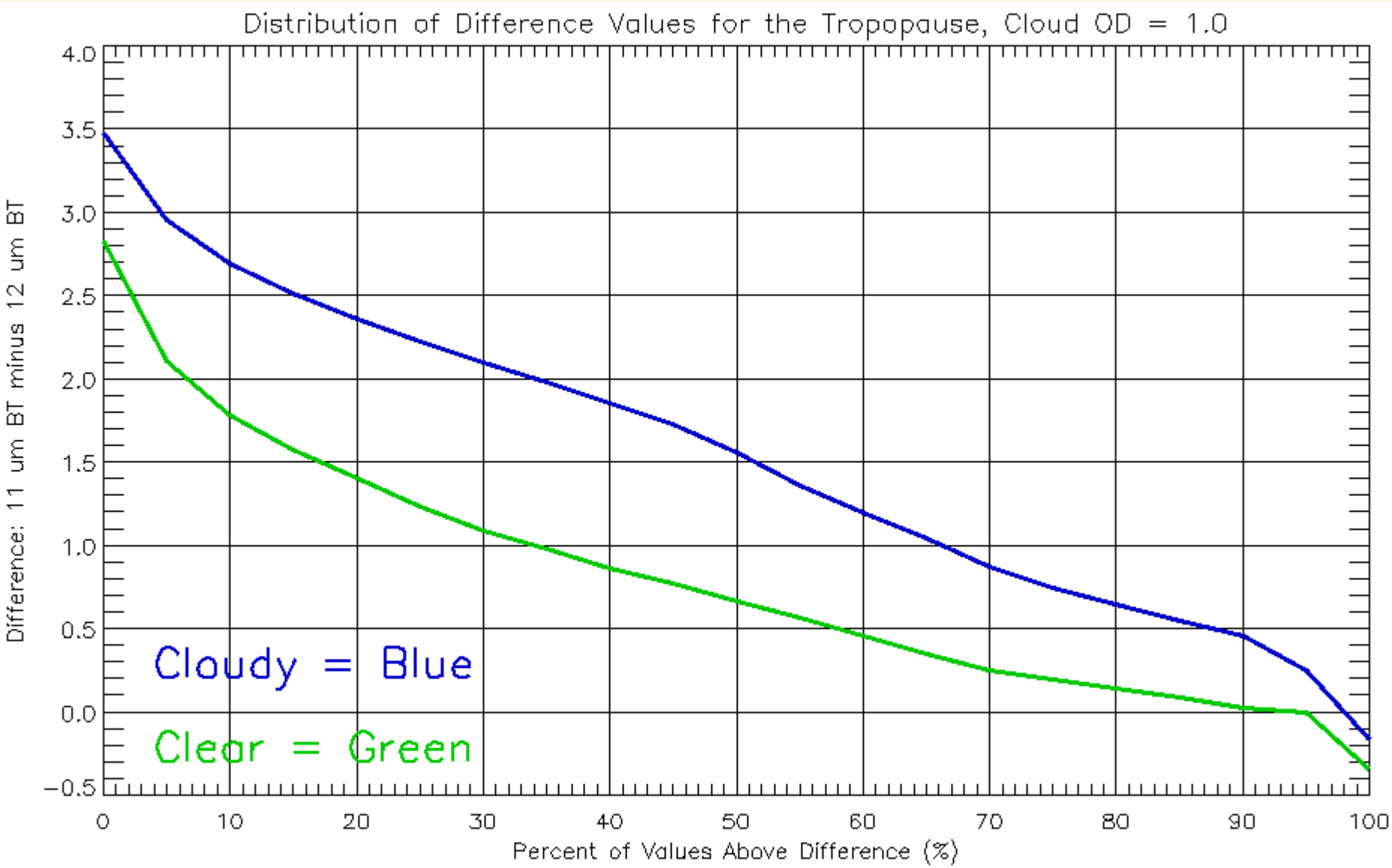
- 8 tropopause layers were possible:
  - 500 mb – 400 mb
  - 400 mb – 300 mb
  - 300 mb – 250 mb
  - 250 mb – 200 mb
  - 200 mb – 150 mb
  - 150 mb – 100 mb
  - 100 mb – 70 mb
  - 70 mb – 50 mb

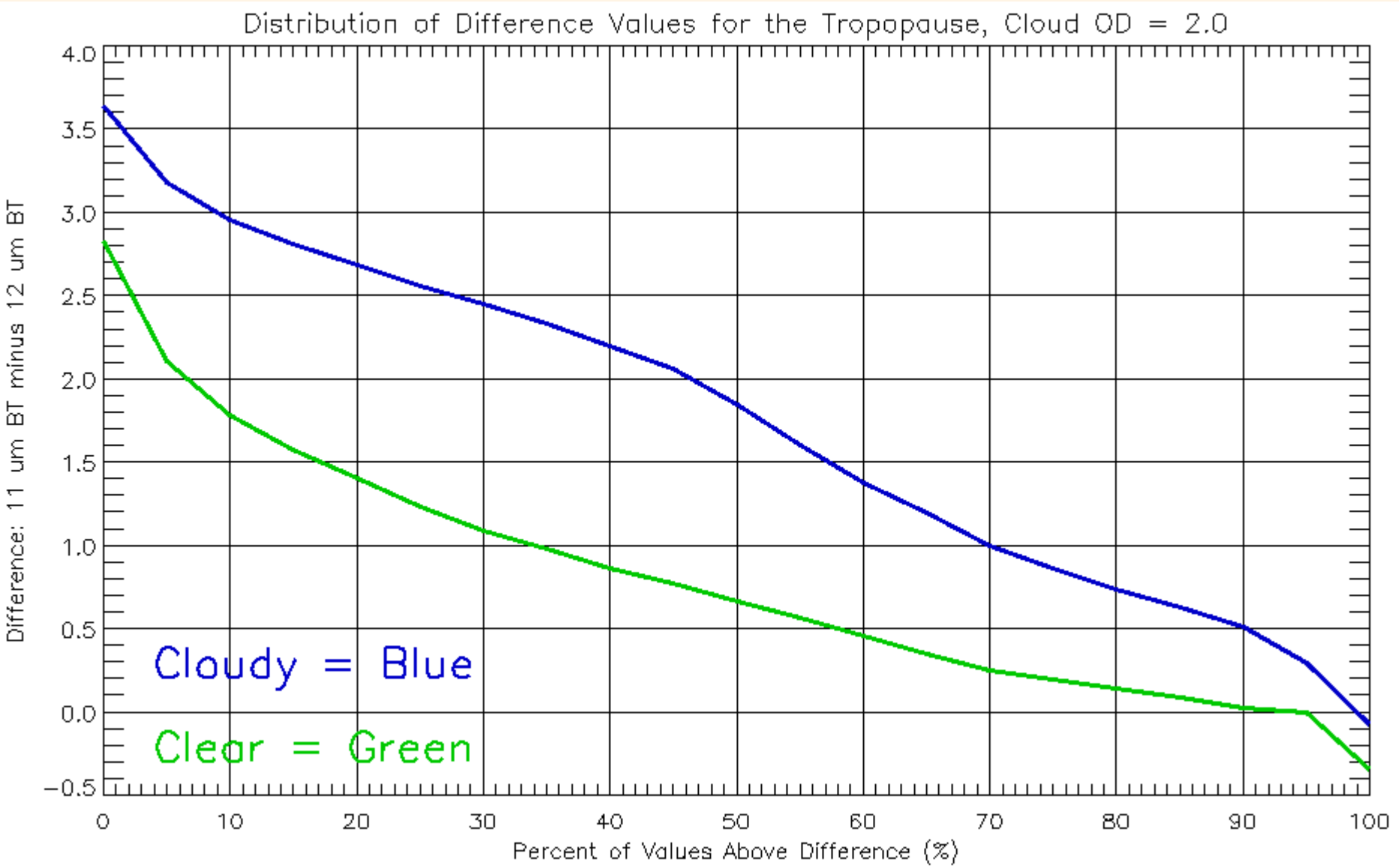

Distribution of Difference Values for the Tropopause, Cloud OD = 0.1
Difference: 11 um BT minus 12 um BT
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
10
20
30
40
50
60
70
80
90
100
Percent of Values Above Difference (%)
Cloudy = Blue
Clear = Green

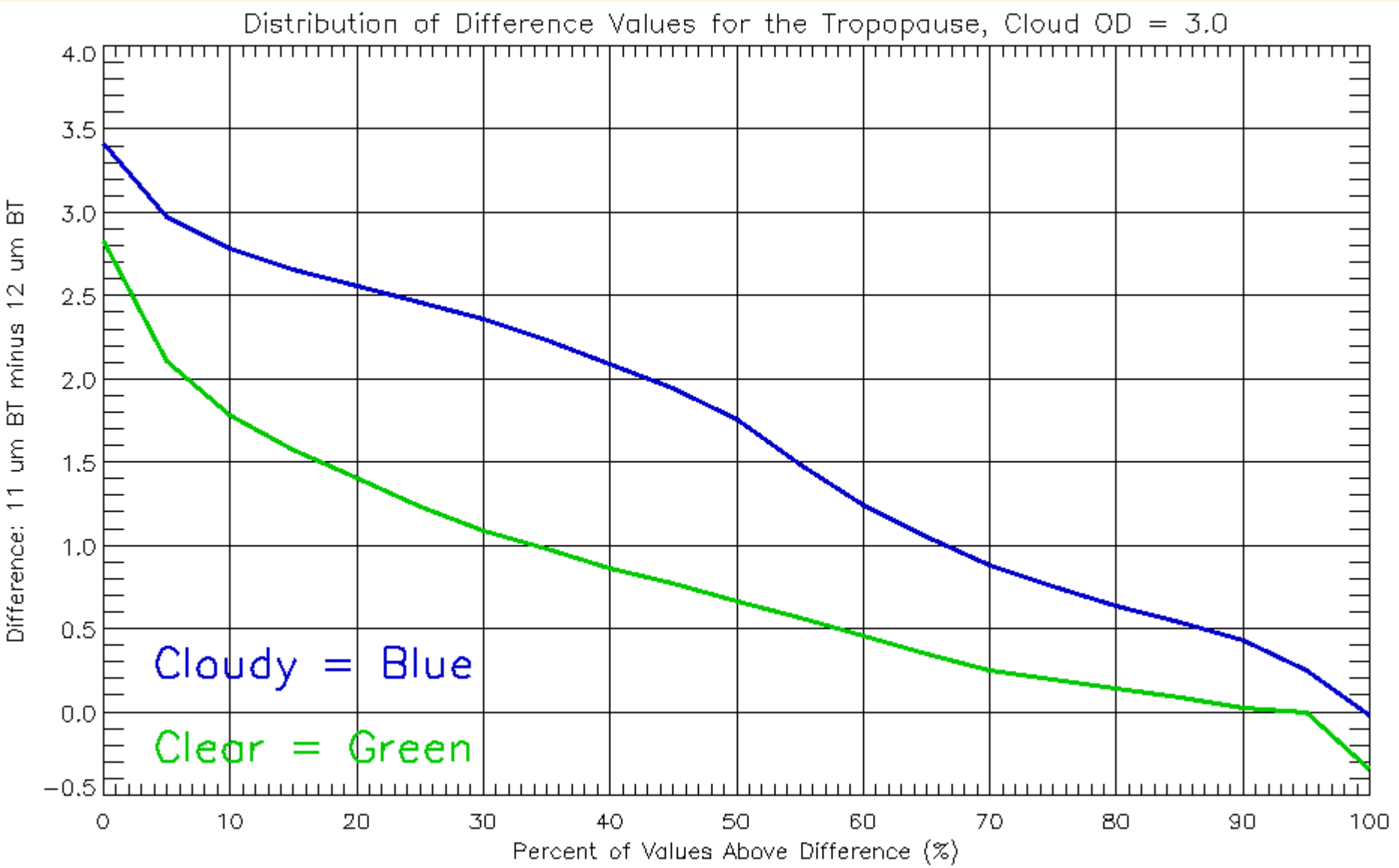

Distribution of Difference Values for the Tropopause, Cloud OD = 0.3
Difference: 11 um BT minus 12 um BT
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
10
20
30
40
50
60
70
80
90
100
Percent of Values Above Difference (%)
Cloudy = Blue
Clear = Green

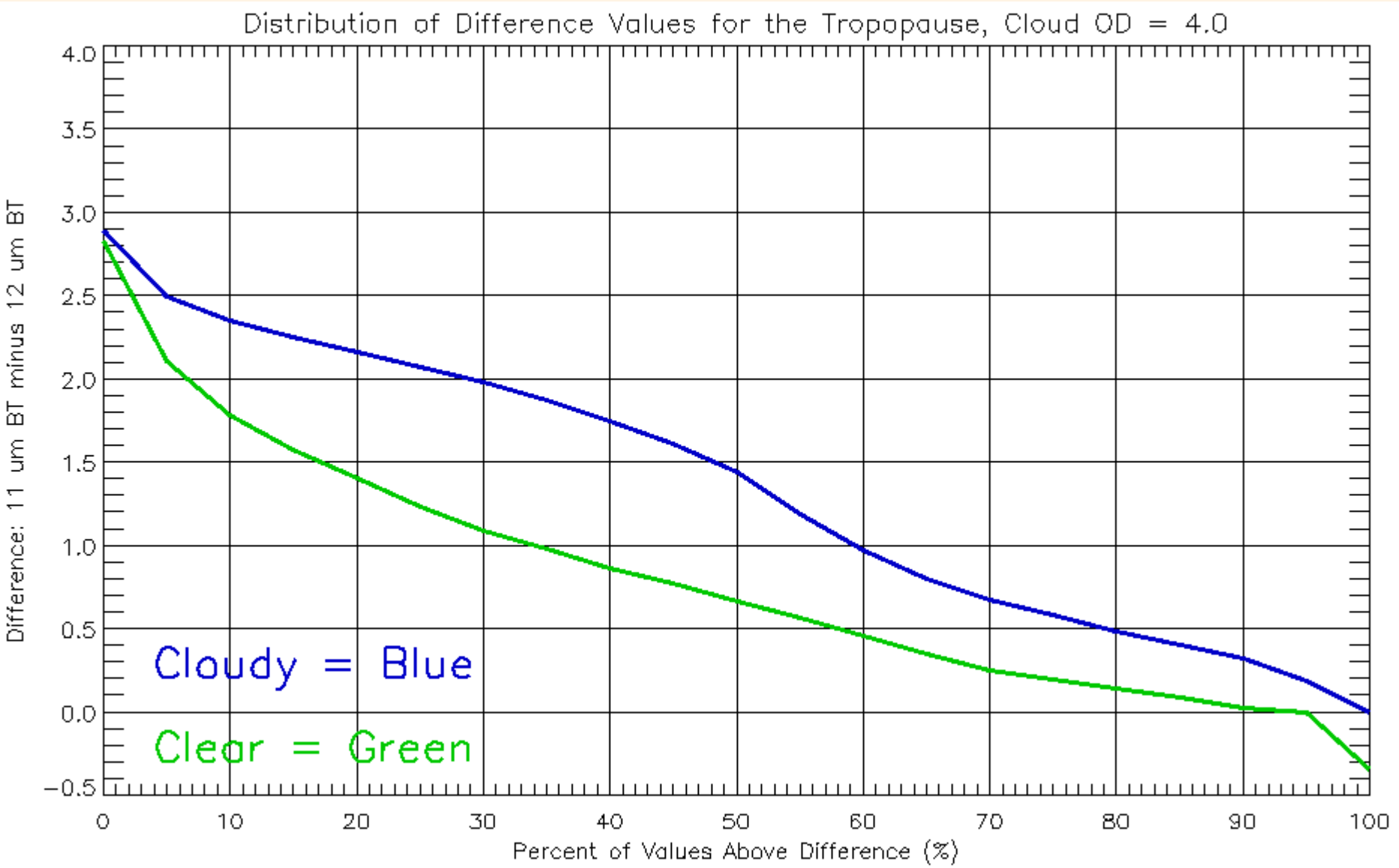

Distribution of Difference Values for the Tropopause, Cloud OD = 0.5
Difference: 11 um BT minus 12 um BT
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
10
20
30
40
50
60
70
80
90
100
Percent of Values Above Difference (%)
Cloudy = Blue
Clear = Green


Distribution of Difference Values for the Tropopause, Cloud OD = 0.75
Difference: 11 um BT minus 12 um BT
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
10
20
30
40
50
60
70
80
90
100
Percent of Values Above Difference (%)
Cloudy = Blue
Clear = Green

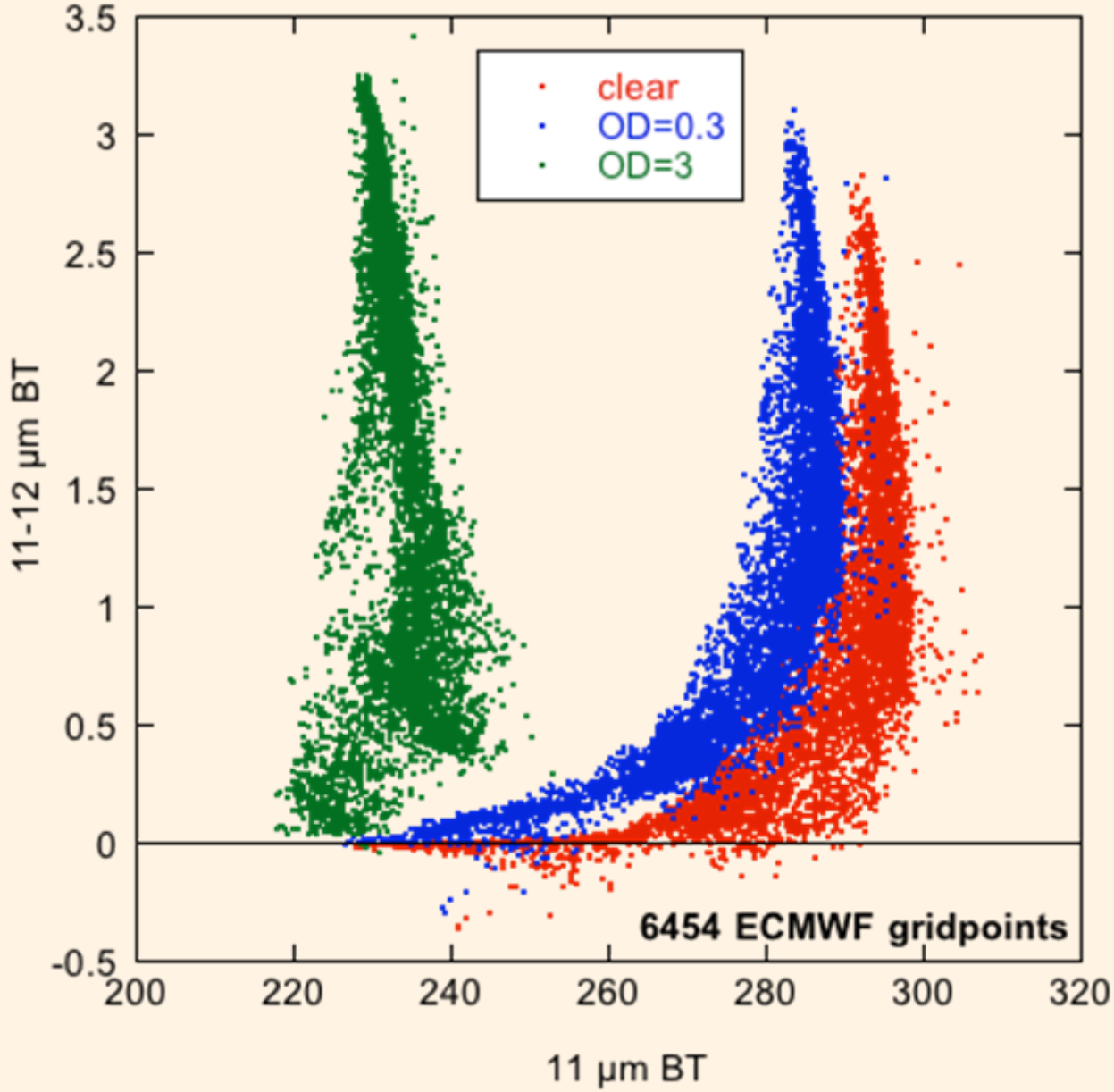

Distribution of Difference Values for the Tropopause, Cloud OD = 1.0
Difference: 11 um BT minus 12 um BT
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
10
20
30
40
50
60
70
80
90
100
Percent of Values Above Difference (%)
Cloudy = Blue
Clear = Green


Distribution of Difference Values for the Tropopause, Cloud OD = 2.0
Difference: 11 um BT minus 12 um BT
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
10
20
30
40
50
60
70
80
90
100
Percent of Values Above Difference (%)
Cloudy = Blue
Clear = Green


Distribution of Difference Values for the Tropopause, Cloud OD = 3.0
Difference: 11 um BT minus 12 um BT
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
10
20
30
40
50
60
70
80
90
100
Percent of Values Above Difference (%)
Cloudy = Blue
Clear = Green


Distribution of Difference Values for the Tropopause, Cloud OD = 4.0
Difference: 11 um BT minus 12 um BT
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0
10
20
30
40
50
60
70
80
90
100
Percent of Values Above Difference (%)
Cloudy = Blue
Clear = Green

Bispectral works better



Additional slides

Simulations

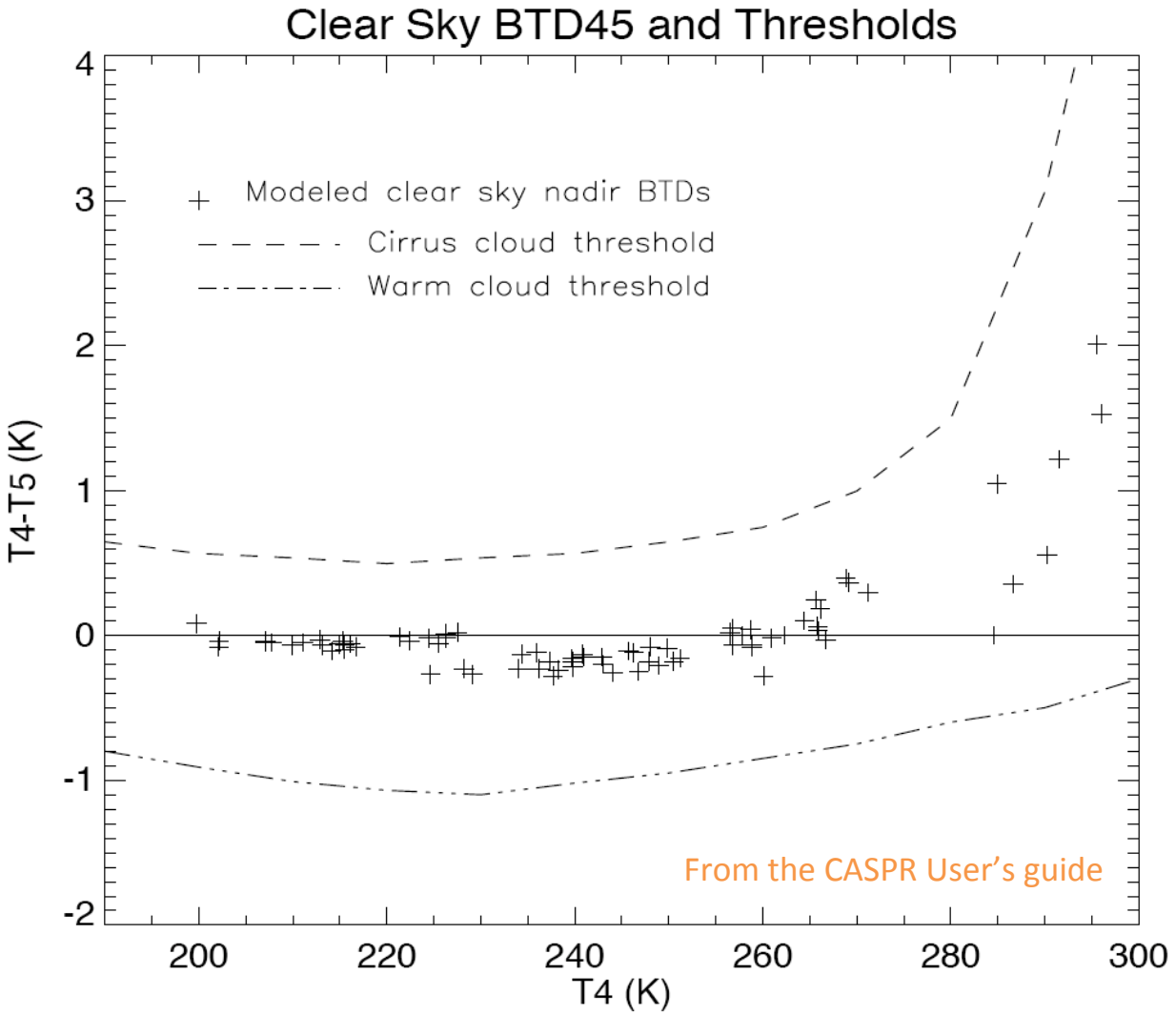


Figure 6. Modeled (*Streamer*) clear sky brightness temperature differences (plus signs) the the cirrus and warm cloud test thresholds (dashed and solid lines, respectively).

Luo et al. (2008) scheme underlying physical basis

Observed spectral variability of various surface types, clouds and shadows