METR 5223: Atmospheric Radiation

Radiative Forcing for Double CO_2 Derived From Modtran

Lecture for Spring 2009, v0.2

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Modtran calculations from:

`understandingtheforecast.org`

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Modtran3 Version 1.3

1976 U.S. Standard Atmosphere

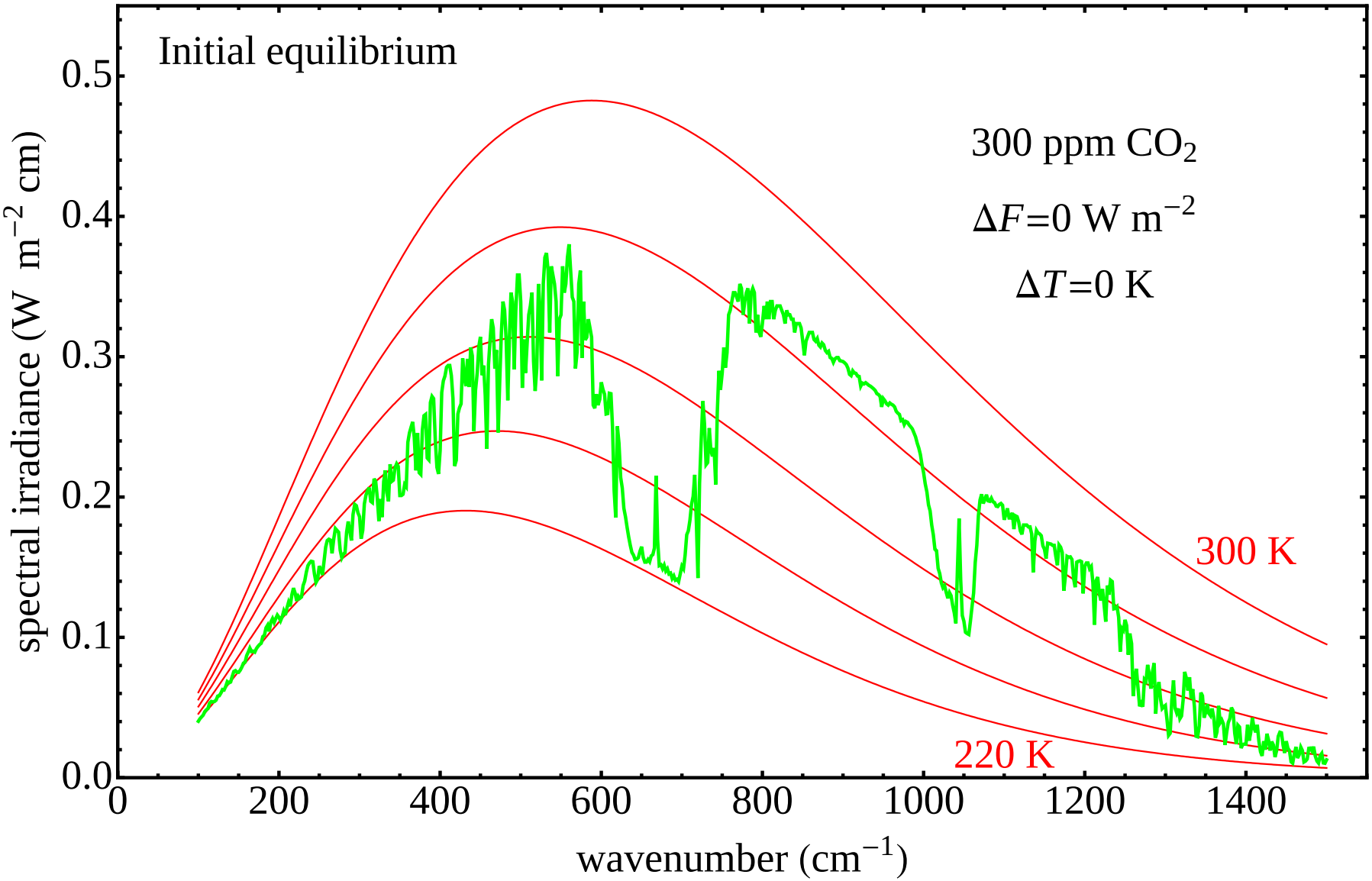
No Clouds or Rain

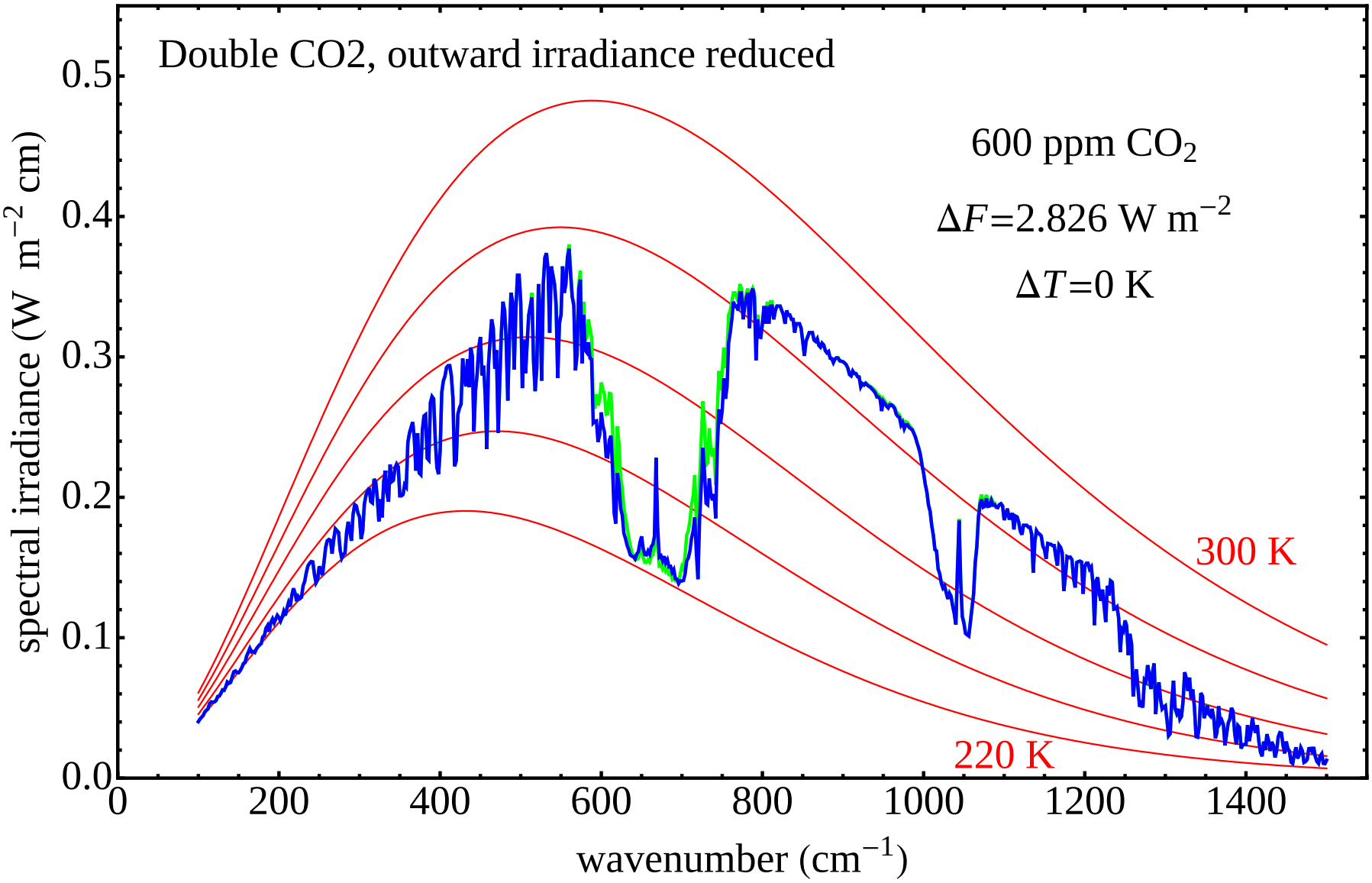
Sensor altitude 70 km, looking down

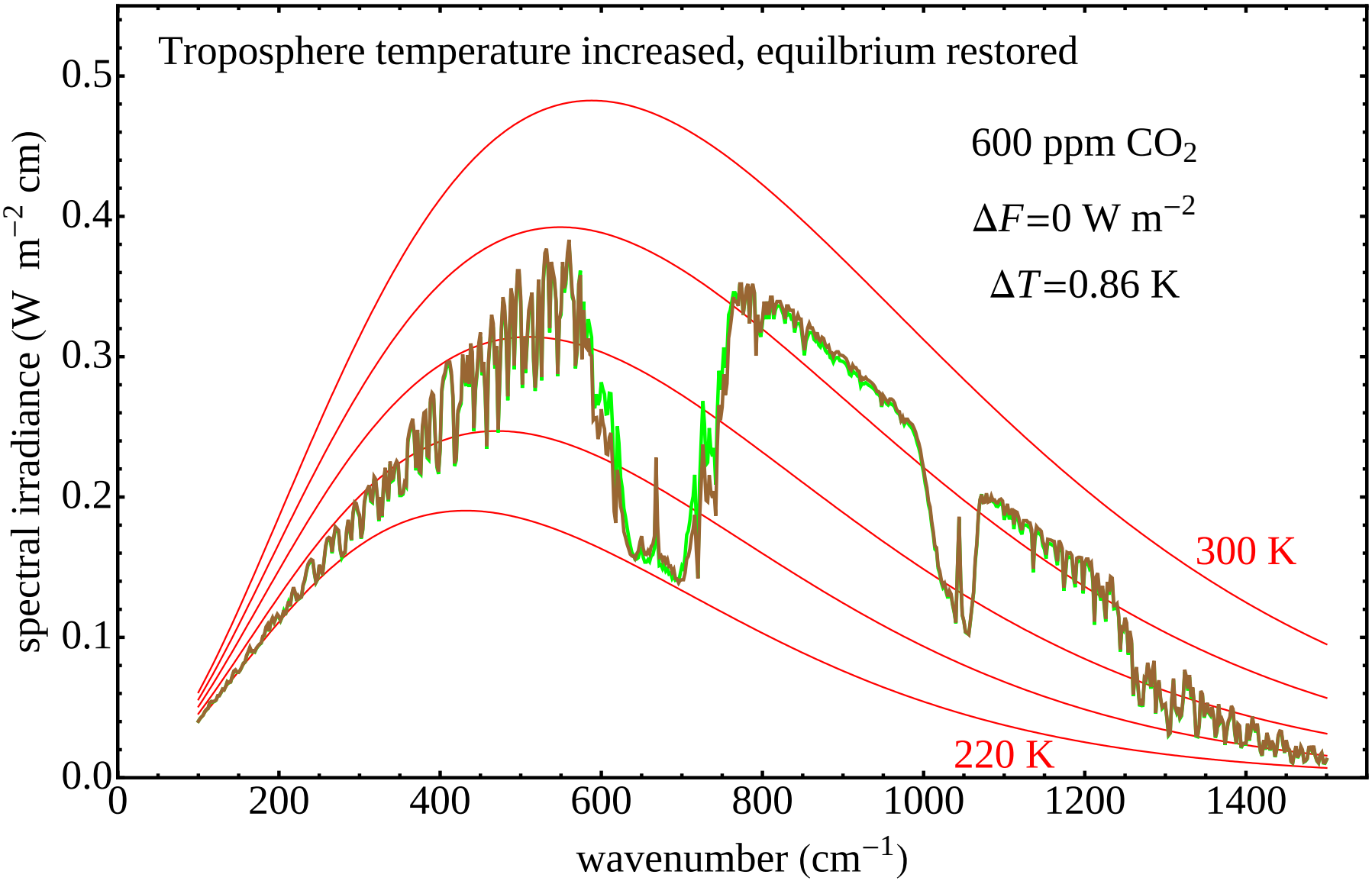
CH4 1.7 ppm

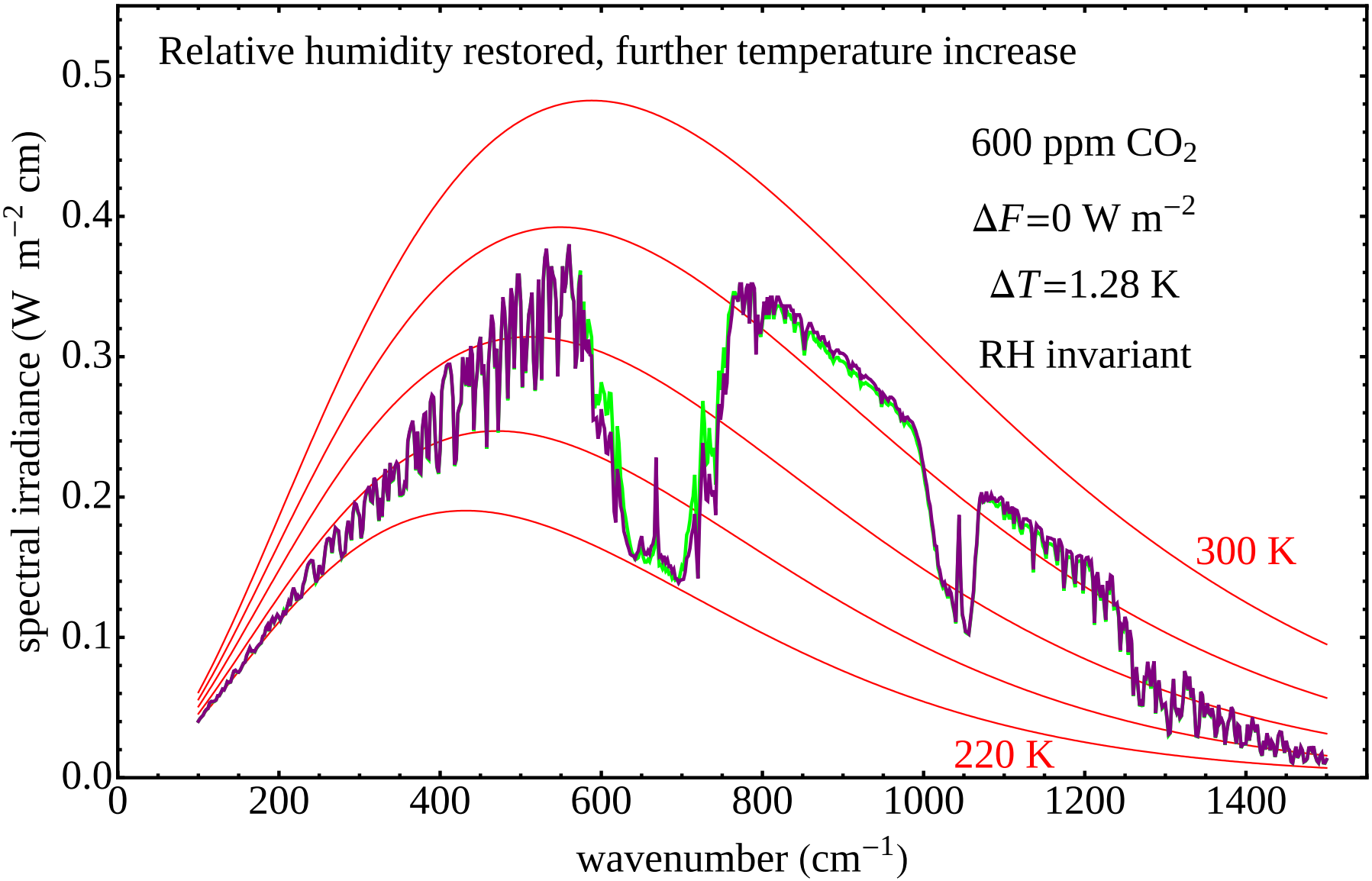
Trop. Ozone 28 ppb

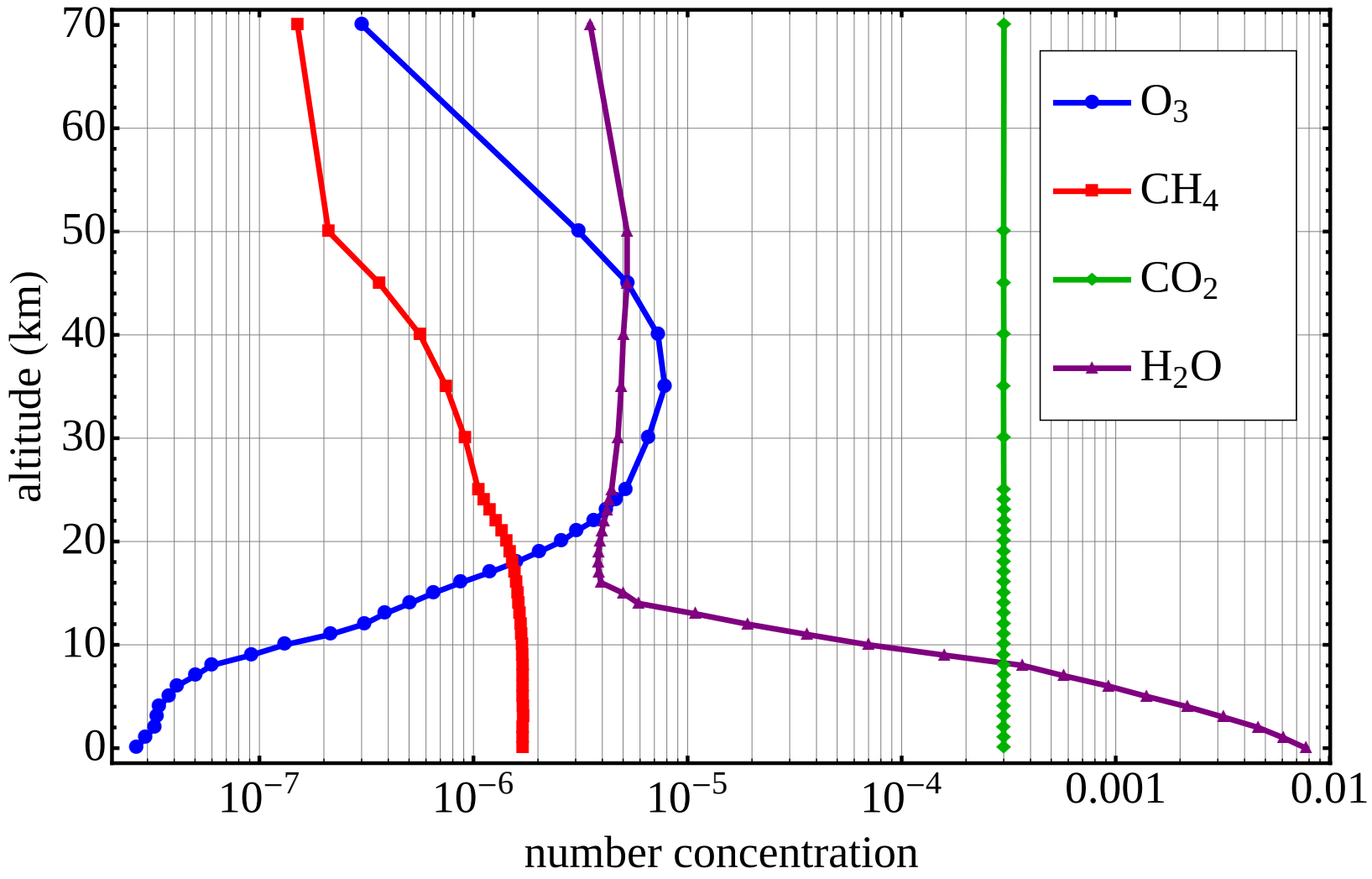
Strat. Ozone scale 1

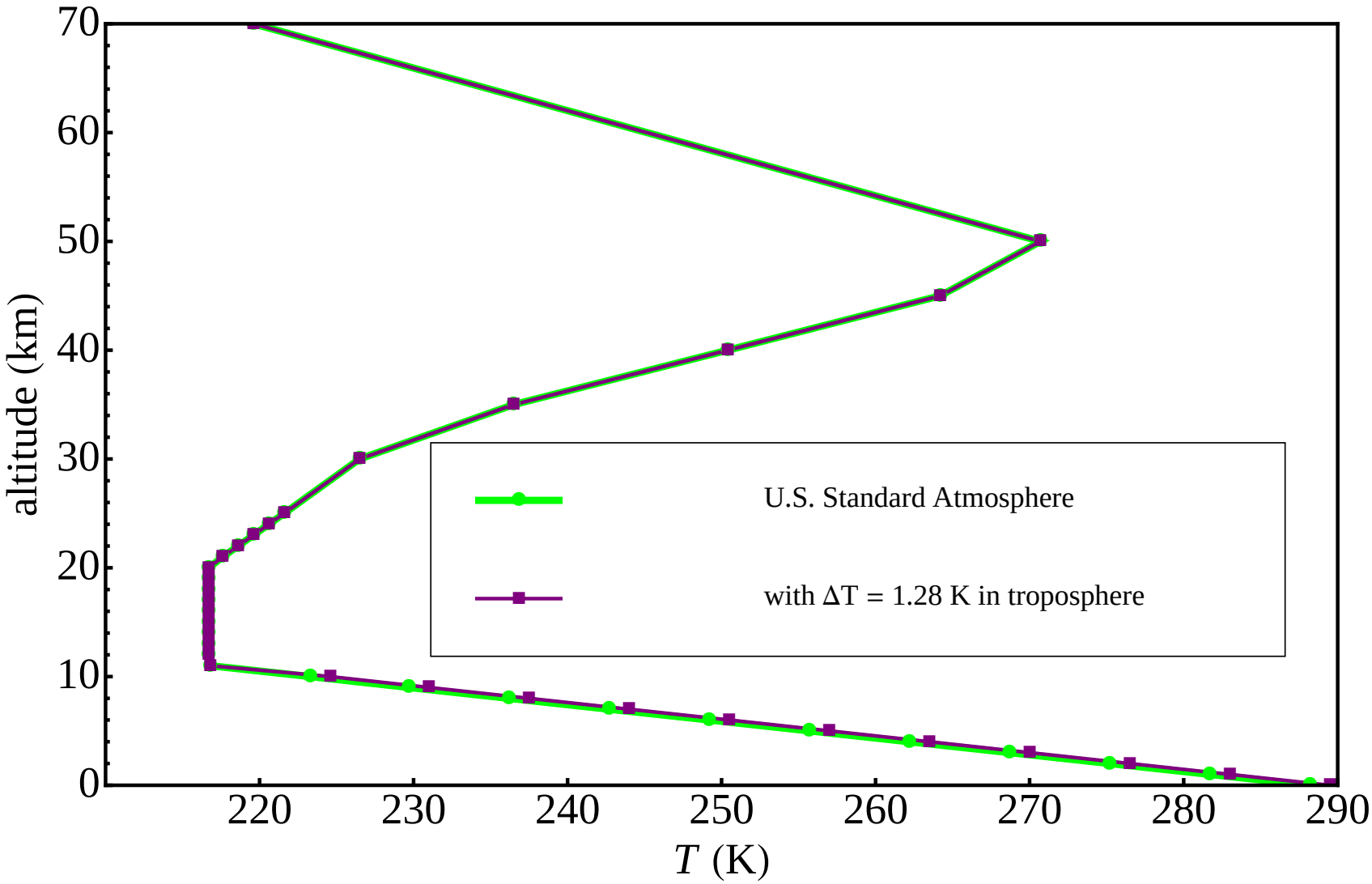

Initial equilibrium
300 ppm CO2
ΔF=0 W m−2
ΔT=0 K
300 K
220 K
spectral irradiance (W m−2 cm)
wavenumber (cm−1)
0.0
0.1
0.2
0.3
0.4
0.5
0
200
400
600
800
1000
1200
1400

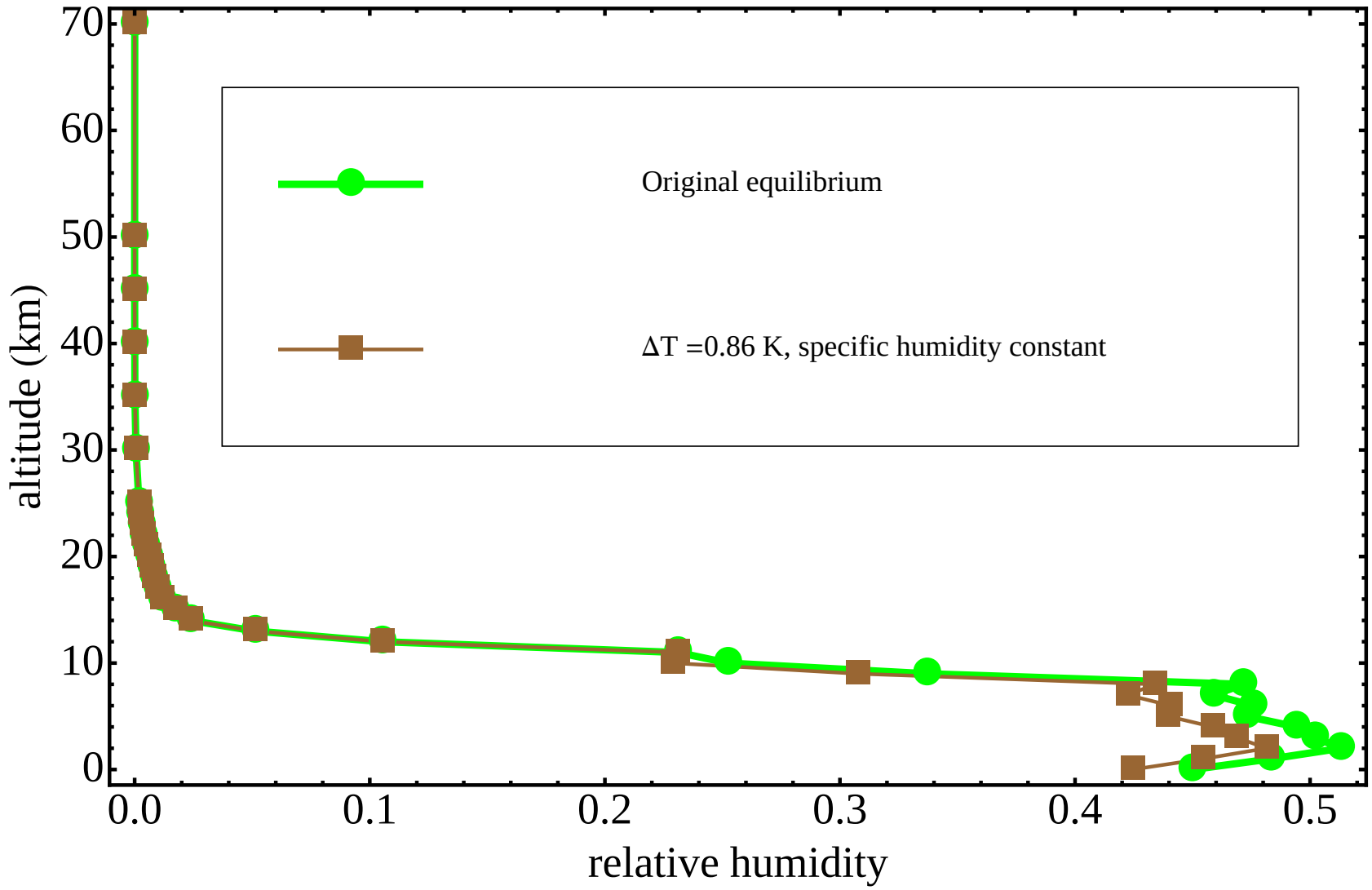

Double CO2, outward irradiance reduced
600 ppm CO_2
ΔF=2.826 W m^{-2}
ΔT=0 K
300 K
220 K
spectral irradiance (W m^{-2} cm)
wavenumber (cm^{-1})
0.0
0.1
0.2
0.3
0.4
0.5
0
200
400
600
800
1000
1200
1400


Troposphere temperature increased, equilbrium restored
600 ppm CO2
ΔF=0 W m−2
ΔT=0.86 K
300 K
220 K
spectral irradiance (W m−2 cm)
wavenumber (cm−1)
0.0
0.1
0.2
0.3
0.4
0.5
0
200
400
600
800
1000
1200
1400


Relative humidity restored, further temperature increase
600 ppm CO2
ΔF=0 W m−2
ΔT=1.28 K
RH invariant
300 K
220 K
spectral irradiance (W m−2 cm)
wavenumber (cm−1)
0.0
0.1
0.2
0.3
0.4
0.5
0
200
400
600
800
1000
1200
1400

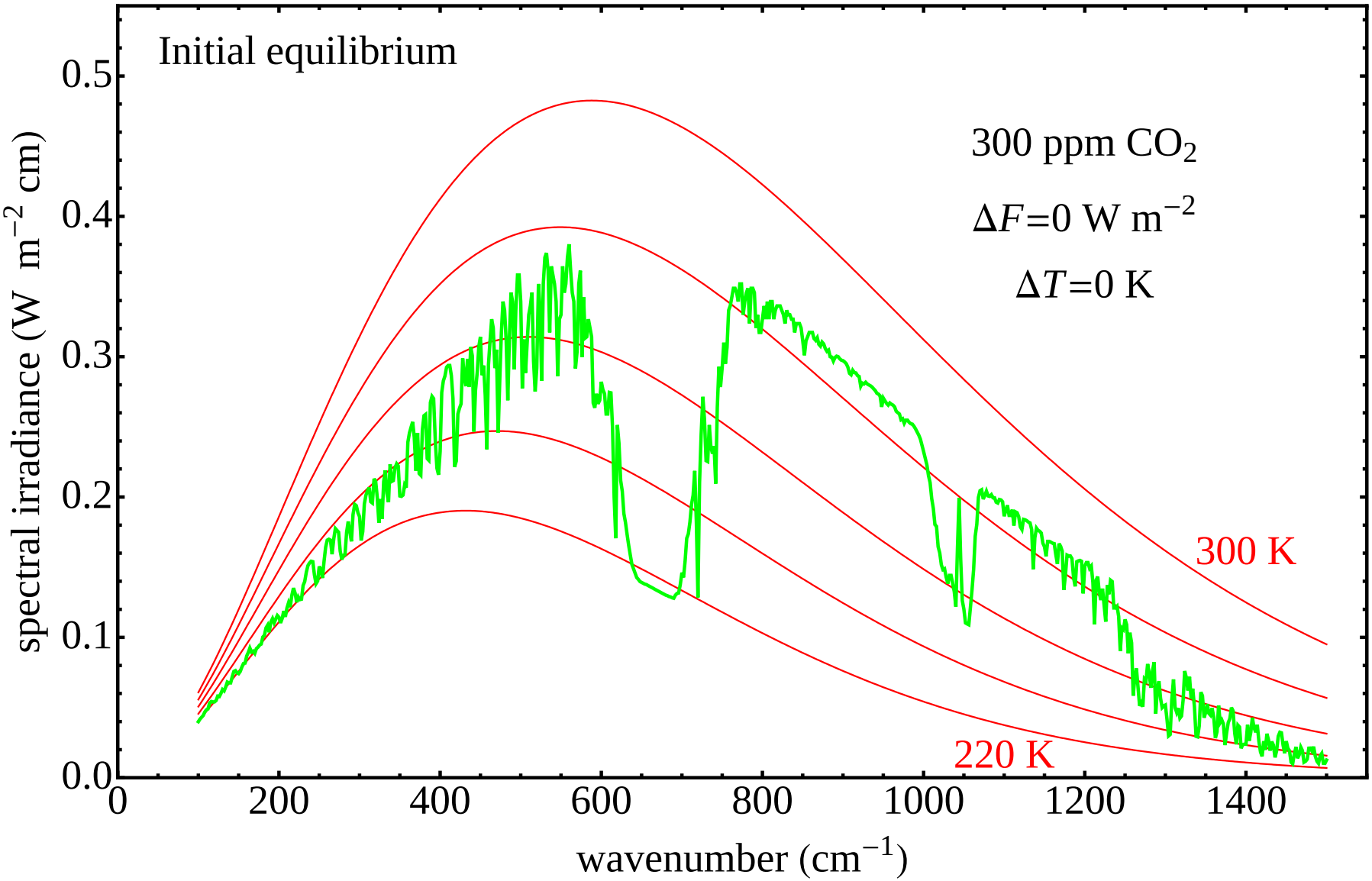

altitude (km)
70
60
50
40
30
20
10
0
10^{-7}
10^{-6}
10^{-5}
10^{-4}
0.001
0.01
number concentration
O_3
CH_4
CO_2
H_2O

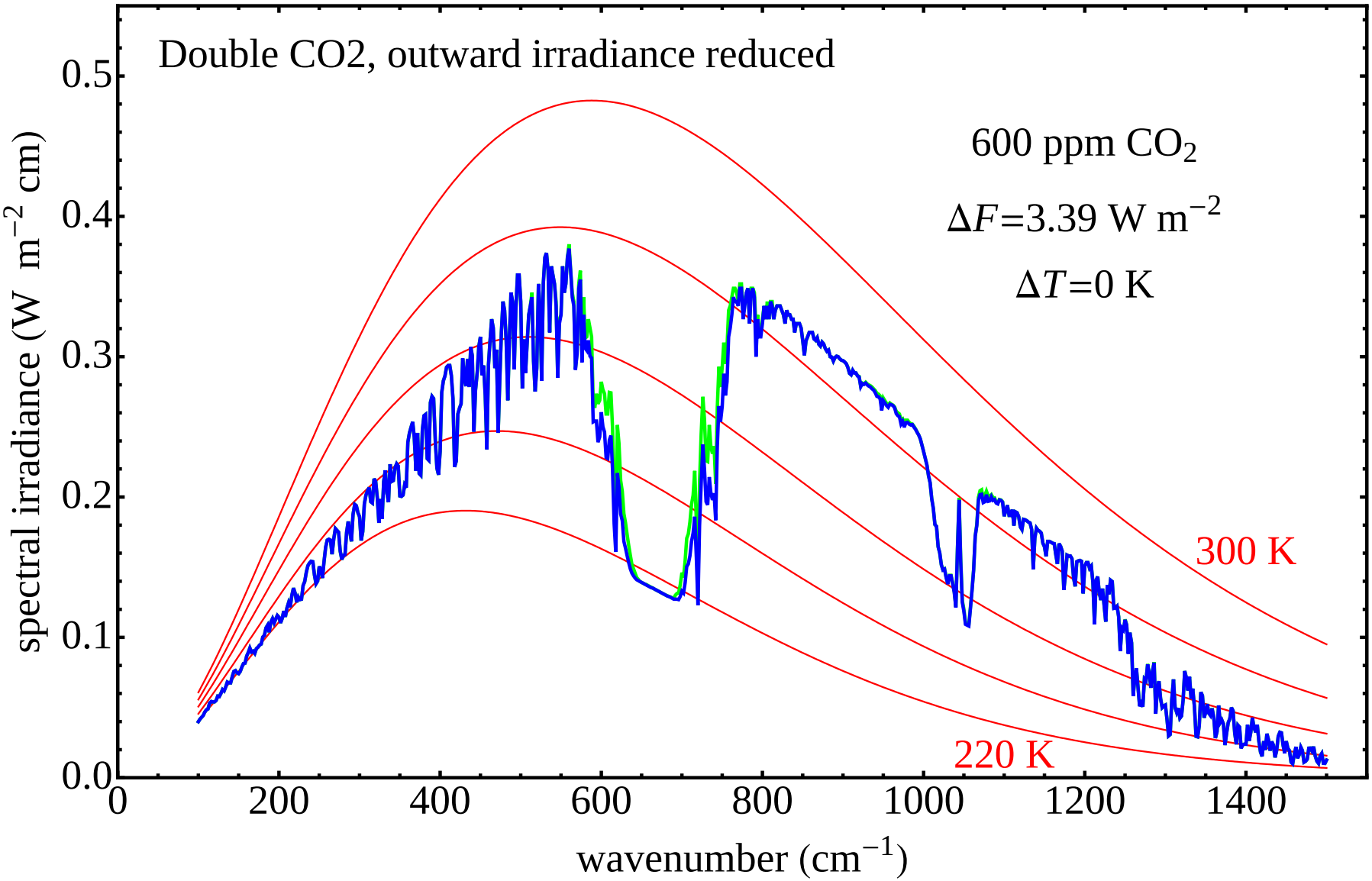

70
60
50
40
30
20
10
0
altitude (km)
220
230
240
250
260
270
280
290
T (K)
U.S. Standard Atmosphere
with ΔT = 1.28 K in troposphere

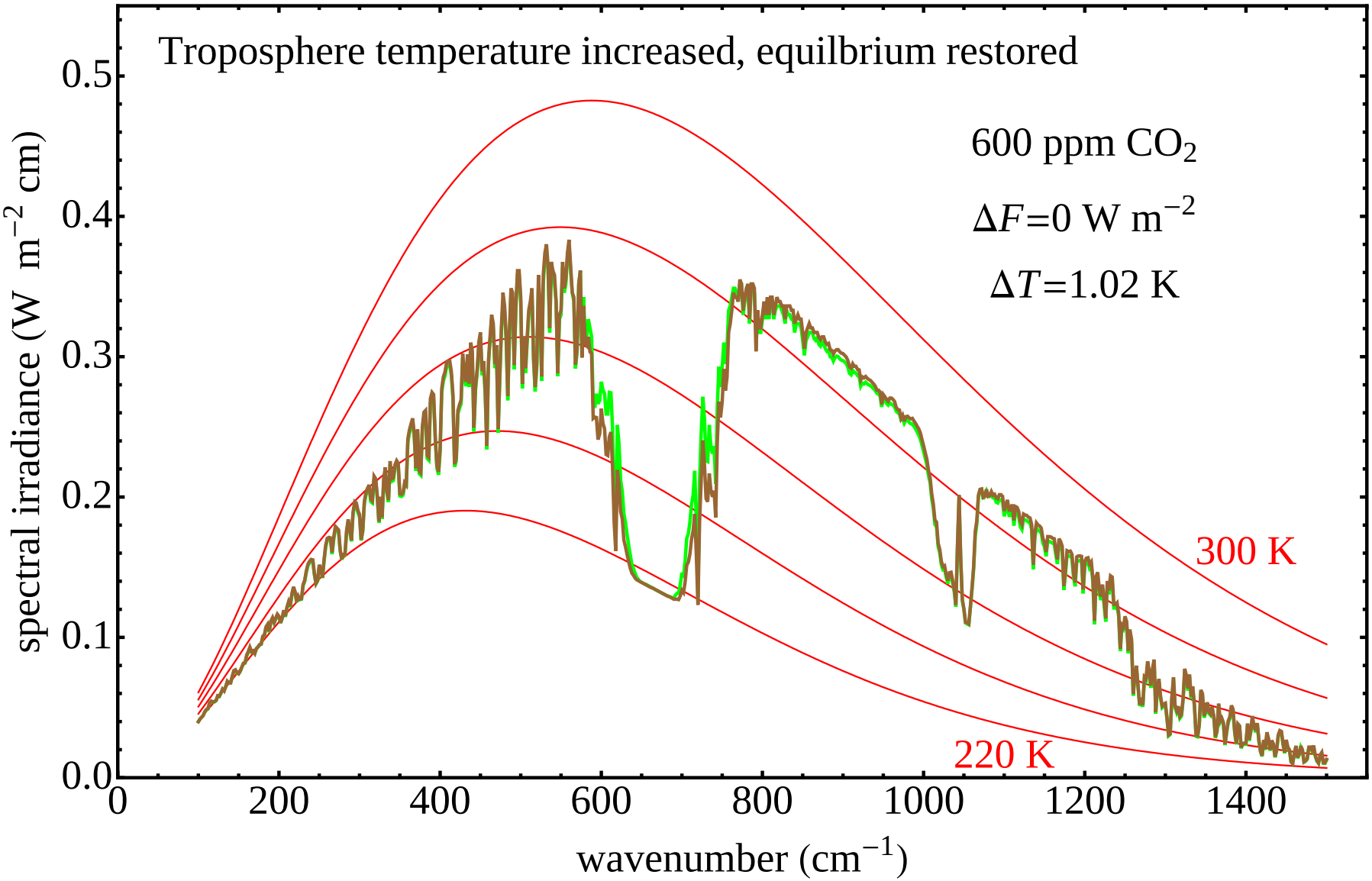

Original equilibrium
ΔT =0.86 K, specific humidity constant
altitude (km)
relative humidity
0
10
20
30
40
50
60
70
0.0
0.1
0.2
0.3
0.4
0.5

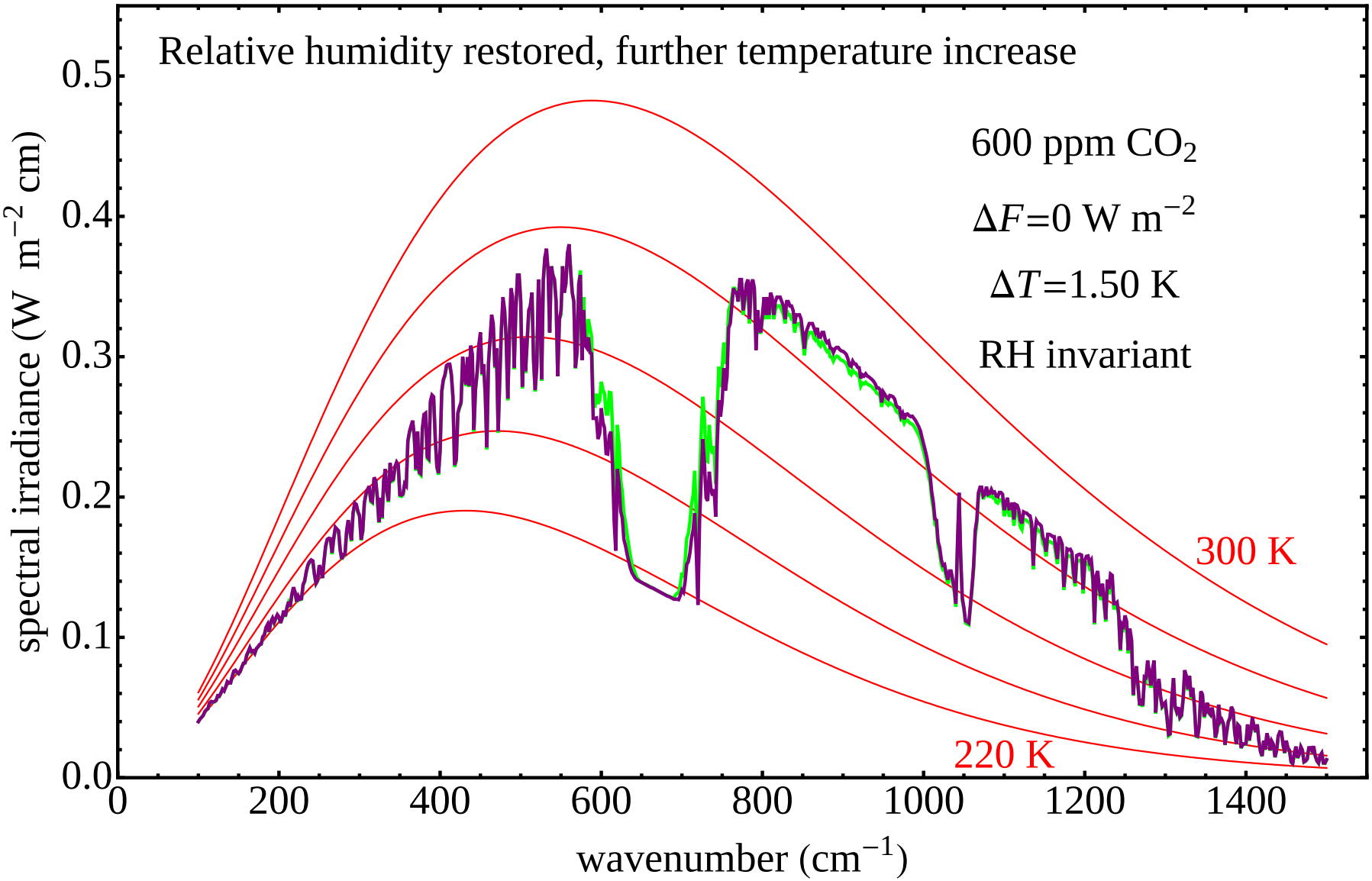
Repeat the analysis with: sensor altitude 20 km, looking down.

This sensor altitude is a surrogate for allowing the stratosphere to *cool* to a new equilibrium temperature in balance with solar absorption, and leave the upward flux contribution from the stratosphere invariant. Thus, analyzing radiative forcing at 20 km for double CO2 calculations is more accurate, if the desire is to include the above feedback process in the radiative forcing.


Initial equilibrium
300 ppm CO2
ΔF=0 W m−2
ΔT=0 K
300 K
220 K
spectral irradiance (W m−2 cm)
wavenumber (cm−1)
0.0
0.1
0.2
0.3
0.4
0.5
0
200
400
600
800
1000
1200
1400


Double CO2, outward irradiance reduced
600 ppm CO_2
ΔF=3.39 W m^{-2}
ΔT=0 K
300 K
220 K
spectral irradiance (W m^{-2} cm)
wavenumber (cm^{-1})
0.0
0.1
0.2
0.3
0.4
0.5
0
200
400
600
800
1000
1200
1400


Troposphere temperature increased, equilbrium restored
600 ppm CO2
ΔF=0 W m−2
ΔT=1.02 K
300 K
220 K
spectral irradiance (W m−2 cm)
wavenumber (cm−1)
0.0
0.1
0.2
0.3
0.4
0.5
0
200
400
600
800
1000
1200
1400


Relative humidity restored, further temperature increase
600 ppm CO2
ΔF=0 W m−2
ΔT=1.50 K
RH invariant
300 K
220 K
spectral irradiance (W m−2 cm)
wavenumber (cm−1)
0.0
0.1
0.2
0.3
0.4
0.5
0
200
400
600
800
1000
1200
1400