The Excel spreadsheet

Step-by-step calculation of spectra from HITRAN Conversion to transmittance Multiplication of transmittance with the Planck function Integration of the Planck function and transmittance products Determination of transmittance of the atmosphere

Columns of the spreadsheet

The starting point is the HITRAN data, which have been converted in Lorentzian lines from 0 to 2400 cm⁻¹ with a spacing of 0.1 cm⁻¹. The columns across the top are

- A. wavenumber
- B. CO2 intensity
- C. cross-sectional density up to TOA (per ppm of CO2) [constant]
- D. ppm CO2 [constant]
- E. cross-sectional density (the product of C. and D.)
- F. A_rel the absorbance to base e (the product of B. and E.)
- G. spherical points source transmittance (=exp{-A_rel})
- H. flux correction (=[exp{-A_rel*1.245} + exp{-A_rel*0.13}]/2)
- I. transmittance (the product of G. and H.)
- J. Temperature [constant]
- K. Planck distribution using wavenumber in A. and temperature in J.)
- L. Plank disttributions times CO2 transmittance (product of I. and K.)

Results of the spreadsheet

The integrated (summed) values of the Planck distribution and Planck distribution times the transmissivity of CO_2 are given in column M. Note that the summed values need to be divided by 100 since the increment of each point is 0.01 cm⁻¹ but the spectral flux units are per cm⁻¹. Since the sum is over 240,000 points it is quite accurate and we do not need to use the trapezoid rule.

In this example, the temperature is 288 K and the integrated flux at the surface of the earth is 391.2 W/m². For the Planck curve with CO_2 absorption the integrated flux is 286.4 W/m². Thus, the total transmissivity is 0.7322 for this example, which only contains CO_2 .

The layout and plotting (using the Excel scatter plot function are shown in the following slides).

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0.01	7.53E-09	234878	4.10E-04	9.63E+01	7.25E-07	0.999999275	0.9999995	0.999998777	288	7.46794E-10	7.46794E-10		
0.02	1.51E-08	234878	4.10E-04	9.63E+01	1.45E-06	0.99999855	0.999999	0.999997553	288	2.9871E-09	2.9871E-09		
0.03	2.26E-08	234878	4.10E-04	9.63E+01	2.18E-06	0.999997825	0.9999985	0.99999633	288	6.72082E-09	6.72079E-09		
0.04	3.01E-08	234878	4.10E-04	9.63E+01	2.90E-06	0.9999971	0.99999801	0.999995106	288	1.19478E-08	1.19478E-08		
0.05	3.76E-08	234878	4.10E-04	9.63E+01	3.63E-06	0.999996375	0.99999751	0.999993883	288	1.8668E-08	1.86679E-08		
0.06	4.52E-08	234878	4.10E-04	9.63E+01	4.35E-06	0.99999565	0.99999701	0.999992659	288	2.68813E-08	2.68811E-08		
0.07	5.27E-08	234878	4.10E-04	9.63E+01	5.07E-06	0.999994925	0.99999651	0.999991436	288	3.65875E-08	3.65871E-08		
0.08	6.02E-08	234878	4.10E-04	9.63E+01	5.80E-06	0.9999942	0.99999601	0.999990213	288	4.77865E-08	4.7786E-08		
0.09	6.78E-08	234878	4.10E-04	9.63E+01	6.52E-06	0.999993475	0.99999551	0.999988989	288	6.04783E-08	6.04776E-08		
0.1	7.53E-08	234878	4.10E-04	9.63E+01	7.25E-06	0.99999275	0.99999502	0.999987766	288	7.46627E-08	7.46618E-08		
0.11	8.28E-08	234878	4.10E-04	9.63E+01	7.97E-06	0.999992025	0.99999452	0.999986542	288	9.03396E-08	9.03384E-08		
0.12	9.03E-08	234878	4.10E-04	9.63E+01	8.70E-06	0.9999913	0.99999402	0.999985319	288	1.07509E-07	1.07507E-07		
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0.15	1.13E-07	234878	4.10E-04	9.63E+01	1.09E-05	0.999989125	0.99999252	0.999981649	288	1.6797E-07	1.67967E-07		
0.16	1.20E-07	234878	4.10E-04	9.63E+01	1.16E-05	0.9999884	0.99999203	0.999980425	288	1.91108E-07	1.91104E-07		
0.17	1.28E-07	234878	4.10E-04	9.63E+01	1.23E-05	0.999987675	0.99999153	0.999979202	288	2.15738E-07	2.15733E-07		
0.18	1.36E-07	234878	4.10E-04	9.63E+01	1.30E-05	0.99998695	0.99999103	0.999977978	288	2.41859E-07	2.41854E-07		
0.19	1.43E-07	234878	4.10E-04	9.63E+01	1.38E-05	0.999986225	0.99999053	0.999976755	288	2.69472E-07	2.69466E-07		
0.2	1.51E-07	234878	4.10E-04	9.63E+01	1.45E-05	0.9999855	0.99999003	0.999975532	288	2.98576E-07	2.98569E-07		
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0.15	1.13E-07	234878	4.10E-04	9.63E+01	1.09E-05	0.99998912	0.999992	0.999981649	288	1.6797E-07	1.67967E-07		
0.16	1.20E-07	234878	4.10E-04	9.63E+01	1.16E-05	0.9999884	0.999992	0.999980425	288	1.91108E-07	1.91104E-07		
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0.2	1.51E-07	234878	4.10E-04	9.63E+01	1.45E-05	0.9999855	0.999990	0.999975532	288	2.98576E-07	2.98569E-07		
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3	0.02	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998557124	0.99900812	0.997566679	288	2.9871E-09	2.97983E-09		
4	0.03	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998557095	0.9990081	0.997566629	288	6.72082E-09	6.70446E-09	Flux (W/m^2)	
5	0.04	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998557065	0.99900808	0.997566579	288	1.19478E-08	1.19187E-08	391.1931453	
6	0.05	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998557036	0.99900806	0.997566529	288	1.8668E-08	1.86226E-08	Ground	
7	0.06	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998557006	0.99900804	0.997566479	288	2.68813E-08	2.68158E-08		
8	0.07	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556977	0.99900802	0.997566429	288	3.65875E-08	3.64984E-08	304.5329103	
9	0.08	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556947	0.999008	0.99756638	288	4.77865E-08	4.76702E-08	TOA	
10	0.09	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556917	0.99900798	0.99756633	288	6.04783E-08	6.03311E-08	0.778472	
11	0.1	1.46E-05	234972	4.20E-04	9.87E+01	1		CO2 inter	nsity		16627E-08	7.4481E-08	CO2 Transmittance	
12	0.11	1.46E-05	234972	4.20E-04	9.87E+01	:		CO2 IIItel	insity)3396E-08	9.01198E-08	0.8	
13	0.12	1.46E-05	234972	4.20E-04	9.87E+01	4.00E+03)7509E-07	1.07247E-07	H2O Trans (Assumed)	
14	0.13	1.46E-05	234972	4.20E-04	9.87E+01	3.50E+03					26171E-07	1.25863E-07		
15	0.14	1.46E-05	234972	4.20E-04	9.87E+01	3.00E+03					16324E-07	1.45968E-07	287.0495924	
16	0.15	1.46E-05	234972	4.20E-04	9.87E+01	5.00ET05					6797E-07	1.67561E-07	T_ground	
17	0.16	1.46E-05	234972	4.20E-04	9.87E+01	2.50E+03)1108E-07	1.90643E-07		
18	0.17	1.46E-05	234972	4.20E-04	9.87E+01	2.00E+03				_	L5738E-07	2.15212E-07		
19	0.18	1.46E-05	234972	4.20E-04	9.87E+01						1859E-07	2.4127E-07		
20	0.19	1.46E-05	234972	4.20E-04	9.87E+01	1.50E+03					59472E-07	2.68816E-07		
21	0.2	1.46E-05	234972	4.20E-04	9.87E+01	1.00E+03)8576E-07	2.9785E-07		
22	0.21	1.46E-05	234972	4.20E-04	9.87E+01	5.00E+02					29172E-07	3.28371E-07		
23	0.22	1.46E-05	234972	4.20E-04	9.87E+01	:	1				51259E-07	3.6038E-07		
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25	0.24	1.46E-05	234972	4.20E-04	9.87E+01	1	, 500	1000 1.	2000	2000	29907E-07	4.28861E-07		
26	0.25	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556464	0.99900767	0.997565566	288	4.66468E-07	4.65332E-07		
27	0.26	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556435	0.99900765	0.997565516	288	5.04519E-07	5.0329E-07		
28	0.27	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556405	0.99900763	0.997565466	288	5.44061E-07	5.42736E-07		
29	0.28	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556375	0.99900761	0.997565416	288	5.85093E-07	5.83669E-07		
30	0.29	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556356	0.99900759	0.997565383	288	6.27616E-07	6.26088E-07		
31	0.3	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556326	0.99900757	0.997565333	288	6.7163E-07	6.69994E-07		
32	0.31	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556297	0.99900755	0.997565283	288	7.17133E-07	7.15387E-07		
33	0.32	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556267	0.99900753	0.997565234	288	7.64127E-07	7.62267E-07		
34	0 33	1 46F-05	224972	4 20F-04	9 87F+01	1 44F-03	0 998556238	0 99900751	0 997565184	288	8 12611F-07	8 10632F-07		
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Column I

		ert Page Layout	t Formulas	Data Review	View Au	utomate He	elp ChemOffice	Chart Desig	gn Format				☐ Comments	d Share	~
Chart	2 ~ !	$\times \checkmark f_x$													~
	А	В	С	D	E	F	G	Н	I	J	K	L	Μ	N	
2	0.01	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998557154	0.99900814	0.997566728	288	7.46794E-10	7.44977E-10			
3	0.02	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998557124	0.99900812	0.997566679	288	2.9871E-09	2.97983E-09			
4	0.03	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998557095	0.9990081	0.997566629	288	6.72082E-09	6.70446E-09	Flux (W/m^2)		
5	0.04	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998557065	0.99900808	0.997566579	288	1.19478E-08	1.19187E-08	391.1931453		
6	0.05	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998557036	0.99900806	0.997566529	288	1.8668E-08	1.86226E-08	Ground		
7	0.06	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998557006	0.99900804	0.997566479	288	2.68813E-08	2.68158E-08			
8	0.07	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556977	0.99900802	0.997566429	288	3.65875E-08	3.64984E-08	304.5329103		
9	0.08	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556947	0.999008	0.99756638	288	4.77865E-08	4.76702E-08	TOA		
10	0.09	1.46E-05	234972	4.20E-04	9.87E+01	<mark>ት 44E-03</mark>	0.998556917	0.99900798	0.99756633	288	6.04783E-08	6.03311E-08	0.778472		
11	0.1	1.46E-05	234972	4.20E-04	9.87E+01	Ť		transmitt	ance		16 + -08	7.4481E-08	CO2 Transmittance		
12	0.11	1.46E-05	234972	4.20E-04	9.87E+01	:		transmitt	ance)3396E-08	9.01198E-08	0.8		
13	0.12	1.46E-05	234972	4.20E-04	9.87E+01	: 1.2					07 🥒 -07	1.07247E-07	H2O Trans (Assumed)		
14	0.13	1.46E-05	234972	4.20E-04	9.87E+01	•					16171E-07	1.25863E-07			
15	0.14	1.46E-05	234972	4.20E-04	9.87E+01	: 1					6 7 -07	1.45968E-07	287.0495924		
16	0.15	1.46E-05	234972	4.20E-04	9.87E+01	. 0.8					6797E-07	1.67561E-07	T_ground		
17	0.16	1.46E-05	234972	4.20E-04	9.87E+01	:					1108E-07	1.90643E-07			
18	0.17	1.46E-05	234972	4.20E-04	9.87E+01	O _{0.6}					9 5738E-07	2.15212E-07			
19	0.18	1.46E-05	234972	4.20E-04	9.87E+01	:					1859E-07	2.4127E-07			
20	0.19	1.46E-05	234972	4.20E-04	9.87E+01	: 0.4					9472E-07	2.68816E-07			
21	0.2	1.46E-05	234972	4.20E-04	9.87E+01	:					8576E-07	2.9785E-07			
22	0.21	1.46E-05	234972	4.20E-04	9.87E+01	: 0.2					9172E-07	3.28371E-07			
23	0.22	1.46E-05	234972	4.20E-04	9.87E+01	:					1259E-07	3.6038E-07			
24	0.23	1.46E-05	234972	4.20E-04	9.87E+01	. 0 .	500 10	000 1500	2000	2500	3000 4838E-07	3.93877E-07			
25	0.24	1.46E-05	234972	4.20E-04	9.87E+01		500 10	O	2000	2500	9907E-07	4.28861E-07			
26	0.25	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556464	0.99900767	0.997565566	288	4.66468E-07	4.65332E-07			
27	0.26	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556435	0.99900765	0.997565516	288	5.04519E-07	5.0329E-07			
28	0.27	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556405	0.99900763	0.997565466	288	5.44061E-07	5.42736E-07			
29	0.28	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556375	0.99900761	0.997565416	288	5.85093E-07	5.83669E-07			
30	0.29	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556356	0.99900759	0.997565383	288	6.27616E-07	6.26088E-07			
31	0.3	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556326	0.99900757	0.997565333	288	6.7163E-07	6.69994E-07			
32	0.31	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556297	0.99900755	0.997565283	288	7.17133E-07	7.15387E-07			
33	0.32	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556267	0.99900753	0.997565234	288	7.64127E-07	7.62267E-07			
34	0 33	1 46F-05	224972	4 20F-04	9 87F+01	1 44F-03	0 998556238	0 99900751	0 997565184	288	8 12611F-07	8 10632F-07			•
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Column K

		ert Page Lay	yout Formulas	Data Review	View A	utomate H	lelp ChemOffice	e Chart Desig	gn Format				Comments	🖻 Share	ř
Chart	t 3 🗸 🗸	$\times \checkmark fx$													~
	А	В	С	D	E	F	G	Н	I.	J	К	L	Μ	N	
2	0.01	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998557154	0.99900814	0.997566728	288	7.46794E-10	7.44977E-10			
3	0.02	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998557124	0.99900812	0.997566679	288	2.9871E-09	2.97983E-09			
4	0.03	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998557095	0.9990081	0.997566629	288	6.72082E-09	6.70446E-09	Flux (W/m^2)		
5	0.04	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998557065	0.99900808	0.997566579	288	1.19478E-08	1.19187E-08	391.1931453		
6	0.05	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998557036	0.99900806	0.997566529	288	1.8668E-08	1.86226E-08	Ground		
7	0.06	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998557006	0.99900804	0.997566479	288	2.68813E-08	2.68158E-08			
8	0.07	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556977	0.99900802	0.997566429	288	3.65875E-08	3.64984E-08	304.5329103		
9	0.08	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556947	0.999008	0.99756638	288	4.77865E-08	4.76702E-08	TOA		
10	0.09	1.46E-05	234972	4.20E-04	9.87E+01	<u>ት 44E-03</u>	0.998556917	0.99900798	0.99756633	288	6.04783E-08	6.03311E-08	0.778472		
11	0.1	1.46E-05	234972	4.20E-04	9.87E+01	Ĭ		planck d			16 + -08	7.4481E-08	CO2 Transmittance		
12	0.11	1.46E-05	234972	4.20E-04	9.87E+01			platick u	JISL)3396E-08	9.01198E-08	0.8		
13	0.12	1.46E-05	234972	4.20E-04	9.87E+01	0.45					07 🖌 -07	1.07247E-07			
14	0.13	1.46E-05	234972	4.20E-04	9.87E+01	: 0.4					6171E-07	1.25863E-07	H2O Trans (Assumed)		
15	0.14	1.46E-05	234972	4.20E-04	9.87E+01	0.35					6 7 -07	1.45968E-07	287.0495924		
16	0.15	1.46E-05	234972	4.20E-04	9.87E+01	. 0.3					6797E-07	1.67561E-07	T_ground		
17	0.16	1.46E-05	234972	4.20E-04	9.87E+01	1					1108E-07	1.90643E-07			
18	0.17	1.46E-05	234972	4.20E-04	9.87E+01	O ^{0.25}		\mathbf{X}			9 5738E-07	2.15212E-07			
19	0.18	1.46E-05	234972	4.20E-04	9.87E+01	0.2		+			1859E-07	2.4127E-07			
20	0.19	1.46E-05	234972	4.20E-04	9.87E+01	0.15		+ + +			9472E-07	2.68816E-07			
21	0.2	1.46E-05	234972	4.20E-04	9.87E+01	0.1					8576E-07	2.9785E-07			
22	0.21	1.46E-05	234972	4.20E-04	9.87E+01	. /					9172E-07	3.28371E-07			
23	0.22	1.46E-05	234972	4.20E-04	9.87E+01	0.05					1259E-07	3.6038E-07			
24	0.23	1.46E-05	234972	4.20E-04	9.87E+01	: 0	500	1500	2000	2500	1/838F-07	3.93877E-07			
25	0.24	1.46E-05	234972	4.20E-04	9.87E+01	0	500 1	1000 1500	0 2000	2500	3000 9907E-07	4.28861E-07			
26	0.25	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556464		0.997565566	288	4.66468E-07	4.65332E-07			
27	0.26	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556435		0.997565516	288	5.04519E-07	5.0329E-07			
28	0.27	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556405		0.997565466	288	5.44061E-07	5.42736E-07			
29	0.28	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556375		0.997565416	288	5.85093E-07	5.83669E-07			
30	0.29	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556356		0.997565383	288	6.27616E-07	6.26088E-07			
31	0.3	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556326		0.997565333	288	6.7163E-07	6.69994E-07			
32	0.31	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556297			288	7.17133E-07	7.15387E-07			
33	0.32	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556267			288	7.64127E-07	7.62267E-07			
34	0.32	1 46F-05	234572	4 20F-04	9.87F+01	1 44F-03	0.998556238		0 997565184	200	8 12611F-07	8 10632F-07			
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Chart 4	4 ~ :	$\times \checkmark f_x$												~
	А	В	С	D	E	F	G	Н	I	J	К	L	М	N 🍝
2	0.01	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998557154	0.99900814	0.997566728	288	7.46794E-10	7.44977E-10		
3	0.02	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998557124	0.99900812	0.997566679	288	2.9871E-09	2.97983E-09		
4	0.03	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998557095	0.9990081	0.997566629	288	6.72082E-09	6.70446E-09	Flux (W/m^2)	
5	0.04	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998557065	0.99900808	0.997566579	288	1.19478E-08	1.19187E-08	391.1931453	
6	0.05	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998557036	0.99900806	0.997566529	288	1.8668E-08	1.86226E-08	Ground	
7	0.06	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998557006	0.99900804	0.997566479	288	2.68813E-08	2.68158E-08	304.5329103	
8	0.07	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556977	0.99900802	0.997566429	288	3.65875E-08	3.64984E-08		
9	0.08	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556947	0.999008	0.99756638	288	4.77865E-08	4.76702E-08	TOA	
10	0.09	1.46E-05	234972	4.20E-04	9.87E+01	<mark>∂</mark> 44E-03	0.998556917	0.99900798	0.99756633	288	6. <mark>04783E</mark> -08	6.03311E-08	0.778472	
11	0.1	1.46E-05	234972	4.20E-04	9.87E+01	Ĭ	nl	anck dist tir	nestrans		6 + -08	7.4481E-08	CO2 Transmittance	
12	0.11	1.46E-05	234972	4.20E-04	9.87E+01		pi)3396E-08	9.01198E-08	0.8	
13	0.12	1.46E-05	234972	4.20E-04	9.87E+01	0.45)7 🖌 -07	1.07247E-07	H2O Trans (Assumed)	
14	0.13	1.46E-05	234972	4.20E-04	9.87E+01	0.4					16171E-07	1.25863E-07	287.0495924	
15	0.14	1.46E-05	234972	4.20E-04	9.87E+01	0.35					16 🝸 -07	1.45968E-07		
16	0.15	1.46E-05	234972	4.20E-04	9.87E+01	. 0.3					6797E-07	1.67561E-07	T_ground	
17	0.16	1.46E-05	234972	4.20E-04	9.87E+01						1108E-07	1.90643E-07		
18	0.17	1.46E-05	234972	4.20E-04	9.87E+01	O ^{0.25}					9 5738E-07	2.15212E-07		
19	0.18	1.46E-05	234972	4.20E-04	9.87E+01	0.2					1859E-07	2.4127E-07		
20	0.19	1.46E-05	234972	4.20E-04	9.87E+01	0.15					9472E-07	2.68816E-07		
21	0.2	1.46E-05	234972	4.20E-04	9.87E+01	0.1					8576E-07	2.9785E-07		
22	0.21	1.46E-05	234972	4.20E-04	9.87E+01	0.05					19172E-07	3.28371E-07		
23	0.22	1.46E-05	234972	4.20E-04	9.87E+01	: /					1259E-07	3.6038E-07		
24	0.23	1.46E-05	234972	4.20E-04	9.87E+01	: 0	500 1	000 1500	0 2000	2500	3000 4838E-07	3.93877E-07		
25	0.24	1.46E-05	234972	4.20E-04	9.87E+01		500 1	0	2000	2000	9907E-07	4.28861E-07		
26	0.25	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556464	0.99900767	0.997565566	288	4.66468E-07	4.65332E-07		
27	0.26	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556435	0.99900765	0.997565516	288	5.04519E-07	5.0329E-07		
28	0.27	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556405	0.99900763	0.997565466	288	5.44061E-07	5.42736E-07		
29	0.28	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556375	0.99900761	0.997565416	288	5.85093E-07	5.83669E-07		
30	0.29	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556356	0.99900759	0.997565383	288	6.27616E-07	6.26088E-07		
31	0.3	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556326	0.99900757	0.997565333	288	6.7163E-07	6.69994E-07		
32	0.31	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556297	0.99900755	0.997565283	288	7.17133E-07	7.15387E-07		
33	0.32	1.46E-05	234972	4.20E-04	9.87E+01	1.44E-03	0.998556267	0.99900753	0.997565234	288	7.64127E-07	7.62267E-07		
34	0 33	1 46F-05	234972	4 20F-04	9 87F+01	1 44F-03	0 998556238	0 99900751	0 997565184	288	8 12611F-07	8 10632F-07		•
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Column M

The Column M gives a single integrated result for the transmittance and global transmittance,

If we either sum (as done below using igor for graphical Convenience) or integrate numerically we find that the flux of bare earth must be 391.1 Wm⁻². We must keep in mind the geometric factor of 4 since the surface area of a sphere is $4\pi R^2$. The earth emits as a sphere, but absorbs as a disc, with area πR^2 . The transmittance at the TOA creates a deficit in the balance that must be filled by the increase in heat and surface radiation of the earth. The temperature of the surface relative to the bare planet is the greenhouse warming. We calculate it to be 32.0 °C.

Flux (W/m^2) 391.1931453 Ground 304.5329103 TOA 0.778472 CO2 Transmittance 0.8H2O Trans (Assumed) 287.0495924 T ground

Calculation of Temperature vs CO₂ ppm

To use the Excel spread sheet you only need to modify column D. There are 250,000 entries in that column. The Excel method is to select the first cell and change it to the desired values. Then point at the lower right-hand corner of the cell and double click. The value will be propagated through the entire column and the calculations will continue. On the far right the integrated flux of the Planck distribution product with CO₂ transmittance will be used to calculate the global transmittance. The transmittance and surface temperature are given.

Column D can be altered to calculate T_{atm}

	A	В	С	D	E	F	G	Н	I.	J	K	L	Μ	N	
1	0.01	0	opt path per ppm	ppm CO2	opt path	A_rel	spherical trans	flux corr	transmittance	temperature	planck dist	planck dist times trans			
2	0.02	0.00E+00	234972	5.60E-04	1.32E+02	0.00E+00	1	1.00E+00	1.00E+00	288	2.9871E-09	2.9871E-09			
3	0.03	0.00E+00	234972	5.60E-04	5+02	0.00E+00	1	1.00E+00	1.00E+00	288	6.72082E-09	6.72082E-09	Flux (W/m^2)		
4	0.04	0.00E+00	234972	5.60E-04	1.3,26 72	0.00E+00	1	1.00E+00	1.00E+00	288	1.19478E-08	1.19478E-08	391.1931453		
5	0.05	0.00E+00	234972	5.60E-04	1.32E+02	00E+00	1	1.00E+00	1.00E+00	288	1.8668E-08	1.8668E-08	Ground		
6	0.06	0.00E+00	234972	5.60E-04	1.32E+02	0.00 20	1	1.00E+00	1.00E+00	288	2.68813E-08	2.68813E-08	300.3109885		
7	0.07	0.00E+00	234972	5.60E-04	1.32E+02	0.00E+00	1	1.00E+00	1.00E+00	288	3.65875E-08	3.65875E-08	TOA		
8	0.08	0.00E+00	234972	5.60E-04	1.32E+02	0.00E+00		1.00E+00	1.00E+00	288	4.77865E-08	4.77865E-08	0.767679578		
9	0.09	0.00E+00	2349	<u> </u>								6.04783E-08	CO2 Transmittance		
10	0.1	0.00E+00	2349 Afte	er enter	ing a ne	ew CO2	2 value se	lected	the lowe	er right-h	and	7.46627E-08	0.8		
11	0.11	0.00E+00	2349		-					-		9.03396E-08	H2O Trans (Assumed)		
12	0.12	0.00E+00	2349 COrr	her and	aouble	e ciick.	This will fi	iii the e	entire co	iumn and	ג	1.07509E-07	288.0531885		
13	0.13	0.00E+00	²³⁴⁹ pro	nagato t	the cal		n to colum					1.26171E-07	T_ground		
14	0.14	0.00E+00	₂₃₄₉ pro	pagale		Juiatio		III IVI.				1.46324E-07			
15	0.15	0.00E+00	234972	5.60E-04	1.32E+02	0.00E+00	1	1.00E+00	1.00E+00	288	1.6797E-07	1.6797E-07			
16	0.16	0.00E+00	234972	5.60E-04	1.32E+02	0.00E+00	1	1.00E+00	1.00E+00	288	1.91108E-07	1.91108E-07			
17	0.17	0.00E+00	234972	5.60E-04	1.32E+02	0.00E+00	1	1.00E+00	1.00E+00	288	2.15738E-07	2.15738E-07			
18	0.18	0.00E+00	234972	5.60E-04	1.32E+02	0.00E+00	1	1.00E+00	1.00E+00	288	2.41859E-07	2.41859E-07			
19	0.19	0.00E+00	234972	5.60E-04	1.32E+02	0.00E+00	1	1.00E+00	1.00E+00	288	2.69472E-07	2.69472E-07			
20	0.2	0.00E+00	234972	5.60E-04	1.32E+02	0.00E+00	1	1.00E+00	1.00E+00	288	2.98576E-07	2.98576E-07			
21	0.21	0.00E+00	234972	5.60E-04	1.32E+02	0.00E+00	1	1.00E+00	1.00E+00	288	3.29172E-07	3.29172E-07			
22	0.22	0.00E+00	234972	5.60E-04	1.32E+02	0.00E+00	1	1.00E+00	1.00E+00	288	3.61259E-07	3.61259E-07			
23	0.23	0.00E+00	234972	5.60E-04	1.32E+02	0.00E+00	1	1.00E+00	1.00E+00	288	3.94838E-07	3.94838E-07			
24	0.24	0.00E+00	234972	5.60E-04	1.32E+02	0.00E+00	1	1.00E+00	1.00E+00	288	4.29907E-07	4.29907E-07			
25	0.25	0.00E+00	234972	5.60E-04	1.32E+02	0.00E+00	1	1.00E+00	1.00E+00	288	4.66468E-07	4.66468E-07			
26	0.26	0.00E+00	234972	5.60E-04	1.32E+02	0.00E+00	1	1.00E+00	1.00E+00	288	5.04519E-07	5.04519E-07			
27	0.27	0.00E+00	234972	5.60E-04	1.32E+02	0.00E+00	1	1.00E+00	1.00E+00	288	5.44061E-07	5.44061E-07			
28	0.28	0.00E+00	234972	5.60E-04	1.32E+02	0.00E+00	1	1.00E+00	1.00E+00	288	5.85093E-07	5.85093E-07			
29	0.29	0.00E+00	234972	5.60E-04	1.32E+02	0.00E+00	1	1.00E+00	1.00E+00	288	6.27616E-07	6.27616E-07			
30	0.3	0.00E+00	234972	5.60E-04	-1.32E+02	0.00E+00	1	1.00E+00	1.00E+00	288	6.7163E-07	6.7163E-07			
31	0.31	0 00F+00	234972	5 60F-04	32F+02	0 00F+00	1	1 00F+00	1 00F+00	288	7 17133F-07	7 17133F-07			•

By input of a series of values of CO_2 ppm in column D one can obtain both transmittance and temperature for each value. The spectra above and series of temperatures and transmittances have also been calculated using Python.

One issue is the length of the files. Typical HITRAN files have tens of thousands of spectral transitions and when given broadening and Gaussian or Lorentzian form the files have circa 250,000 points to have a resolution of 0.01 cm⁻¹.

In practice we were unable to implement python scripts for 250,000 points. We used 25,000 points and repeated all above spreadsheet calculations with 25,000 points (and a resolution of 0.1 cm⁻¹. Given a broadening of $\gamma = 0.1$ cm⁻¹ the resolution is a real concern.

The Python scripts are functional using 25,000 points. By eye the spectra, transmittance and so on appear identical. However, the numerical values of the depends on CO_2 ppm are approximately 50% smaller for the 0.1 cm⁻¹ spacing compared to the 0.01 cm⁻¹ spacing.

Goal of the spreadsheet is to calculate global transmittance and temperature changes as a function of CO₂ ppm

