Advanced radiation and remote sensing

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Exercise No. 5 – Jacobian and opacity rule

1. Run the Jupyter Notebook jacobian.ipynb to calculate the brightness temperature spectrum in nadir direction and the zenith opacity around the 183 GHz line of water vapor for a midlatitude summer atmosphere. Answer following question:

   - Are there window regions?

   The atmospheric temperature profile for the calculation was:

Pressure [hPa]	**Temperature** [K]	**Altitude** [km]
1013.0	294.2	0
902.0	289.7	1
802.0	285.2	2
710.0	279.2	3
628.0	273.2	4
554.0	267.2	5
487.0	261.2	6
426.0	254.7	7
372.0	248.2	8
324.0	241.7	9
281.0	235.3	10
243.0	228.8	11
209.0	222.3	12
179.0	215.8	13
153.0	215.7	14
130.0	215.7	15
111.0	215.7	16
95.0	215.7	17
81.2	216.8	18
69.5	217.9	19
59.5	219.2	20

   Consider the table and answer following questions:

   - From which altitude does the radiation at the peak of the line (≈ 183 GHz) originate?
   - From which altitude does the radiation at the wing (150 GHz) originate?

2. Change the variable `highlight_frequency` from `None` to any desired frequency in [Hz] within the range of the brightness temperature spectrum of task 1 and rerun the last notebook cell. This will calculate the water vapor Jacobian and the opacity τ between the top of the atmosphere z_{TOA} and altitude z for the selected frequency. Additionally, a circle marks the selected frequency in the plot of the brightness temperature spectrum and in the plot of the zenith opacity.

   Write down the altitude of the Jacobian peak and the altitude where the opacity reaches 1 for some different frequencies and answer following questions:

   - Why are the altitude where the opacity reaches 1 and the altitude of the Jacobian peak not exactly the same?
   - Why are the Jacobians sometimes positive and sometimes negative?