A Mid-Res Grid of Contribution Functions Characterizing Brown Dwarf Atmospheres

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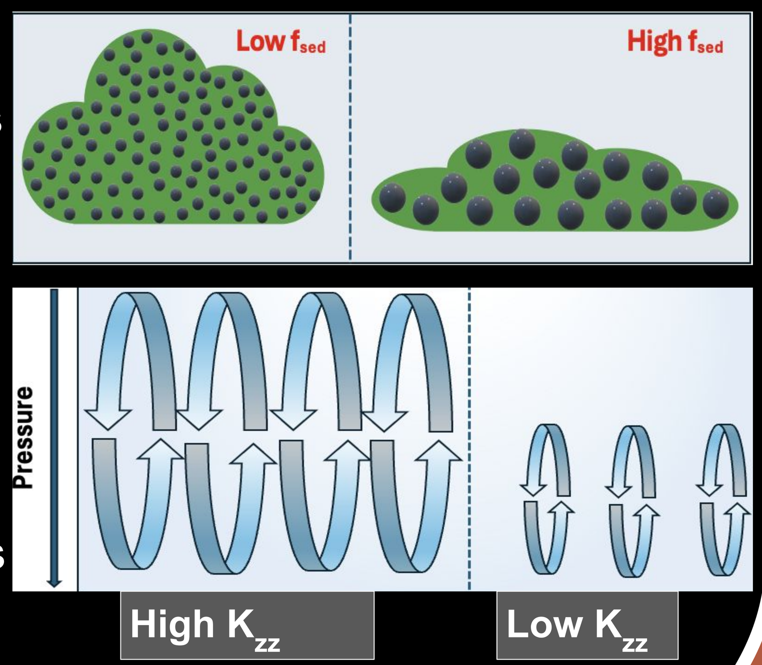
Brown Dwarfs

Brown dwarfs share molecular, cloudy atmospheres with gas giants . Their isolated nature makes them easier to observe: HST achieves SNR ~300[1] and JWST's NIRSpec reaches ~400[2]. This high-quality data lets us test and refine exoplanet atmospheric models and characterization techniques. Potential clouds hosted by these bodies effect how deep we are able to peer in to their atmospheres. We present a Mid-Res grid of contribution functions spanning L/LT & T type cloudy and cloud-free models of brown dwarfs.

In this work, we describe clouds using parameters commonly found in the literature: the sedimentation efficiency parameter[3,4](f_{sed}) and the eddy diffusion coefficient [4]($\mathbf{K_{zz}}$). We find that atmospheres in chemical equilibrium show that high $\mathbf{K_{zz}}$ models produce results comparable to those of a cloud-free profile..



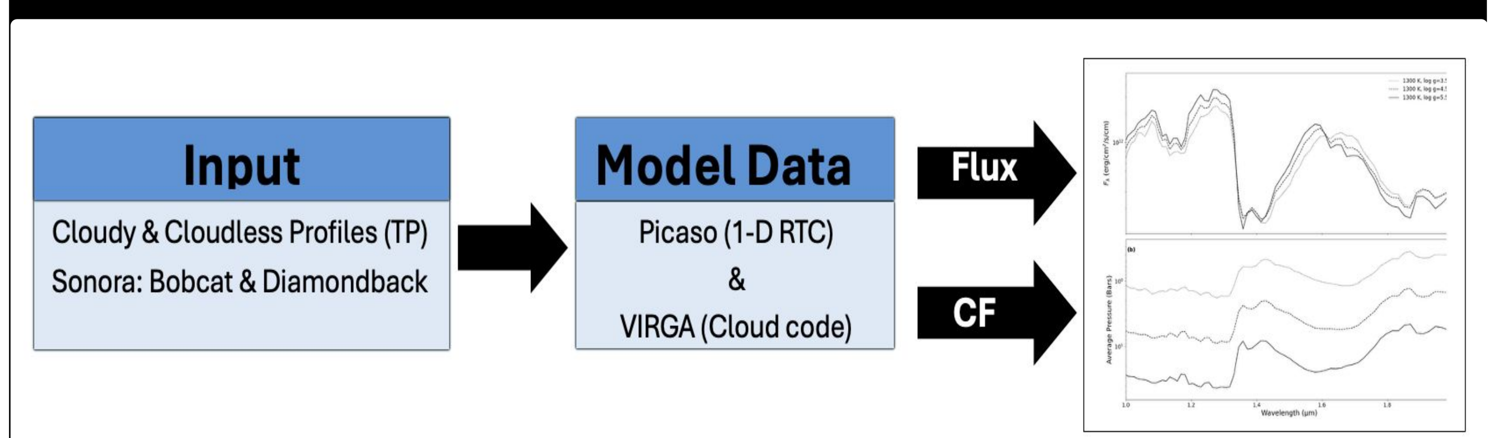
Research Goals

1. **Build an Accessible Model Grid**
Considering Effects of : Teff, log g, cloud parameters (f_{sed}/K_{zz}), and chemical equilibrium. We leverage existing Temperature-Pressure(TP) profiles SONORA Diamondback[5], SONORA Bobcat[6] and VIRGA[7] for cloud modeling to run as input to the PICASO[8] 1-D radiative transfer code .

2. **Quantify Wavelength Band Sensitivities**
Identify which photometric bands (e.g., J, H, K) are most diagnostic for key physical parameters in brown dwarfs. This analysis will help observers optimize filter selection and more accurately interpret spectral data, ultimately enabling deeper insight into the 3D structure and dynamics of exoatmospheres.

3. **Empower the Community**
Offer the grid data on an intuitive interface (e.g., web portal, plotting tools) so astronomers can query model behavior in real-time.

Methodology



Grid Structure

Constructing models at Low-Resolution and Mid-Resolution. Our grids covers :

-Effective Temperature Range: 500 K - 2000 K

-Gravity Ranges: log = 3.5, 4.0, 4.5, 5.0 & 5.5

- Cloud Characteristics: K_{zz} = 10^8, 10^9, 10^{10}, 10^{11} & 10^{12}

-Cloud Characteristics: fsed =1, 2,3,4 & 8

Key Findings

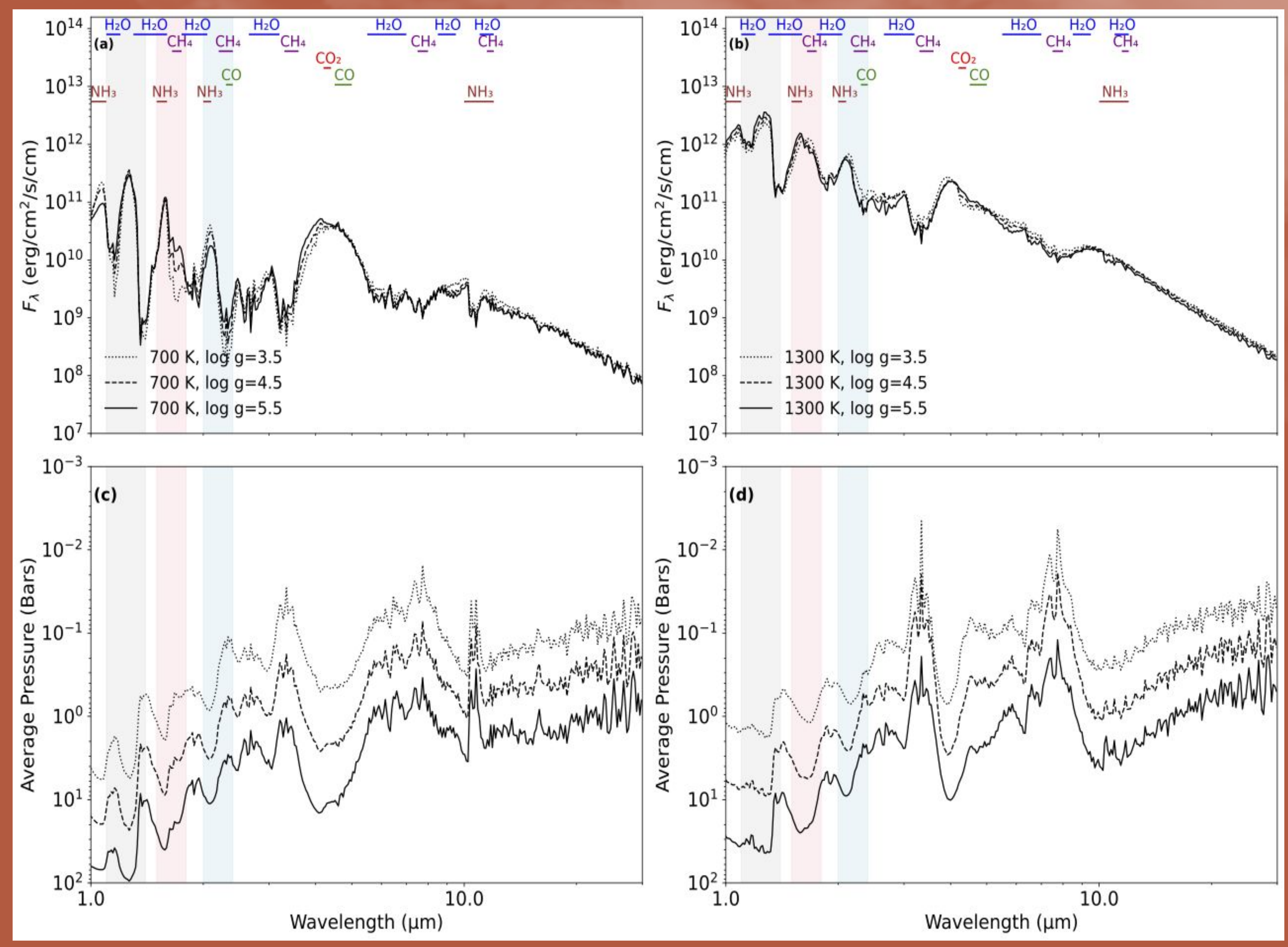


Figure 1 Cloud-Free models of T & L/T object spectra and the respective average pressures probed.

Parameter	Trend	Details
$\mathbf{K_{zz}}$	Decreasing K_{zz} $\rightarrow$ lower pressures probed (higher altitudes)	Strongest impact at low T_{eff} and thick clouds (low f_{sed})
T_{eff}	Increasing T_{eff} $\rightarrow$ less sensitivity to K_{zz}	Pressure curves converge at high T_{eff}, especially for $f_{sed} = 8$
f_{sed}	Increasing f_{sed} $\rightarrow$ thinner clouds, deeper pressures probed	High f_{sed} reduces cloud opacity, allowing deeper emission
Gravity	Increasing $\log g$ $\rightarrow$ deeper pressures probled (higher pressures due to a compressed atmosphere)	High $\log g$ profile pressure diffences show more pronounced decreases in pressure difference across increasing f_{sed}, and K_{zz}; emission originates from denser layers
	Decreasing $\log g$ $\rightarrow$ higher altitudes probed (lower pressures)	Enhances the effect of K_{zz}; broader separation between vertical mixing profiles
J-band (1.1–1.4 μm)	Most sensitive spectral window	Greatest contrast across K_{zz}, f_{sed}, and $\log g$, especially at low T_{eff}
H/K Bands(1.5–2.4 μm)	Moderate sensitivity	Pressure differences shift to higher T_{eff} and appear strongest at low-to-mid $\log g$

Figure 2 Summary table and of the apparent trends for the grid based on parameters.

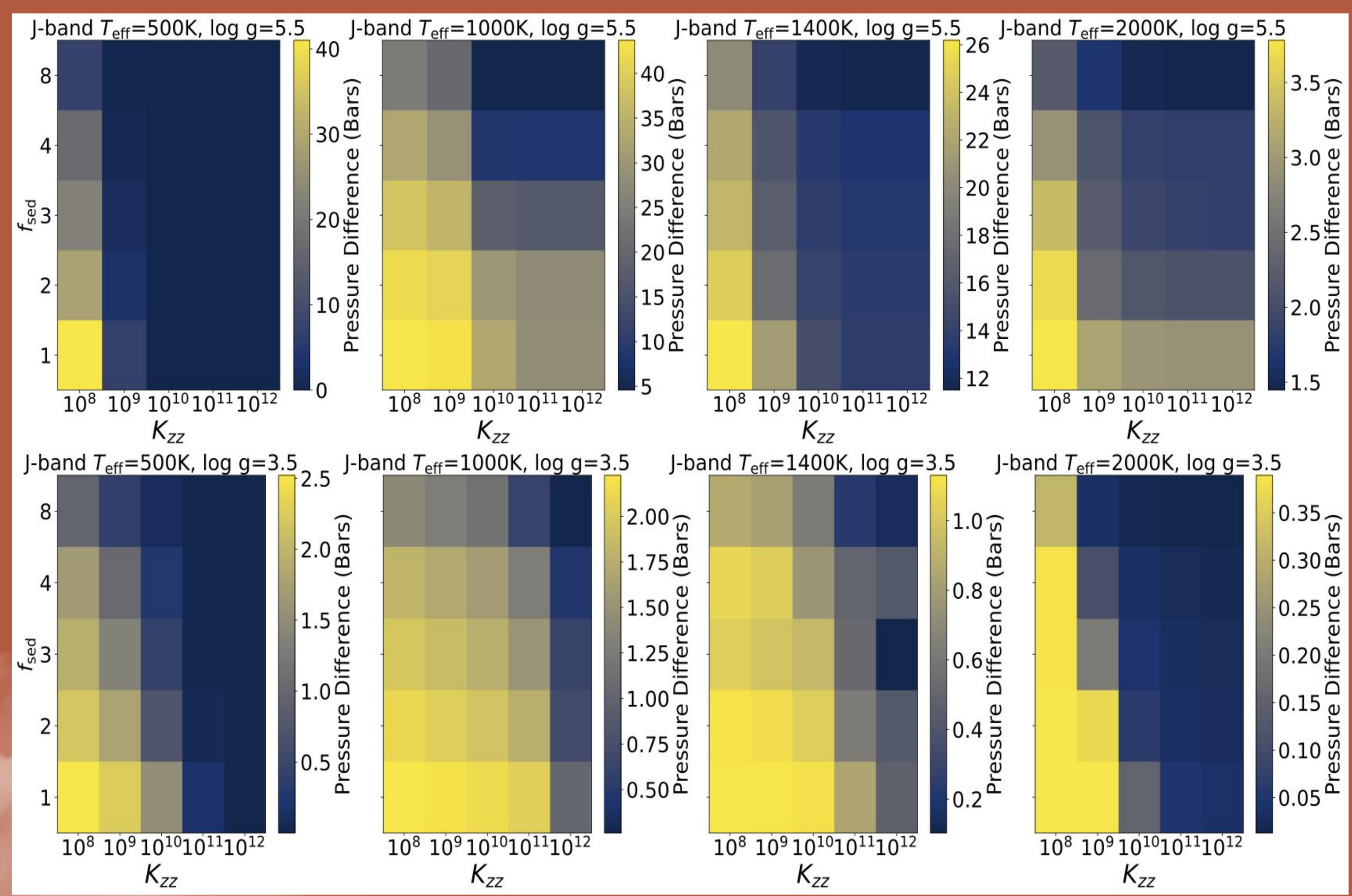


Figure 3 A heat map comparing the average pressure probed difference; Cloudy vs Cloud-free - the top panel row the shows highest gravity in our grid (5.5) while the bottom row shows the lowest(3.5).

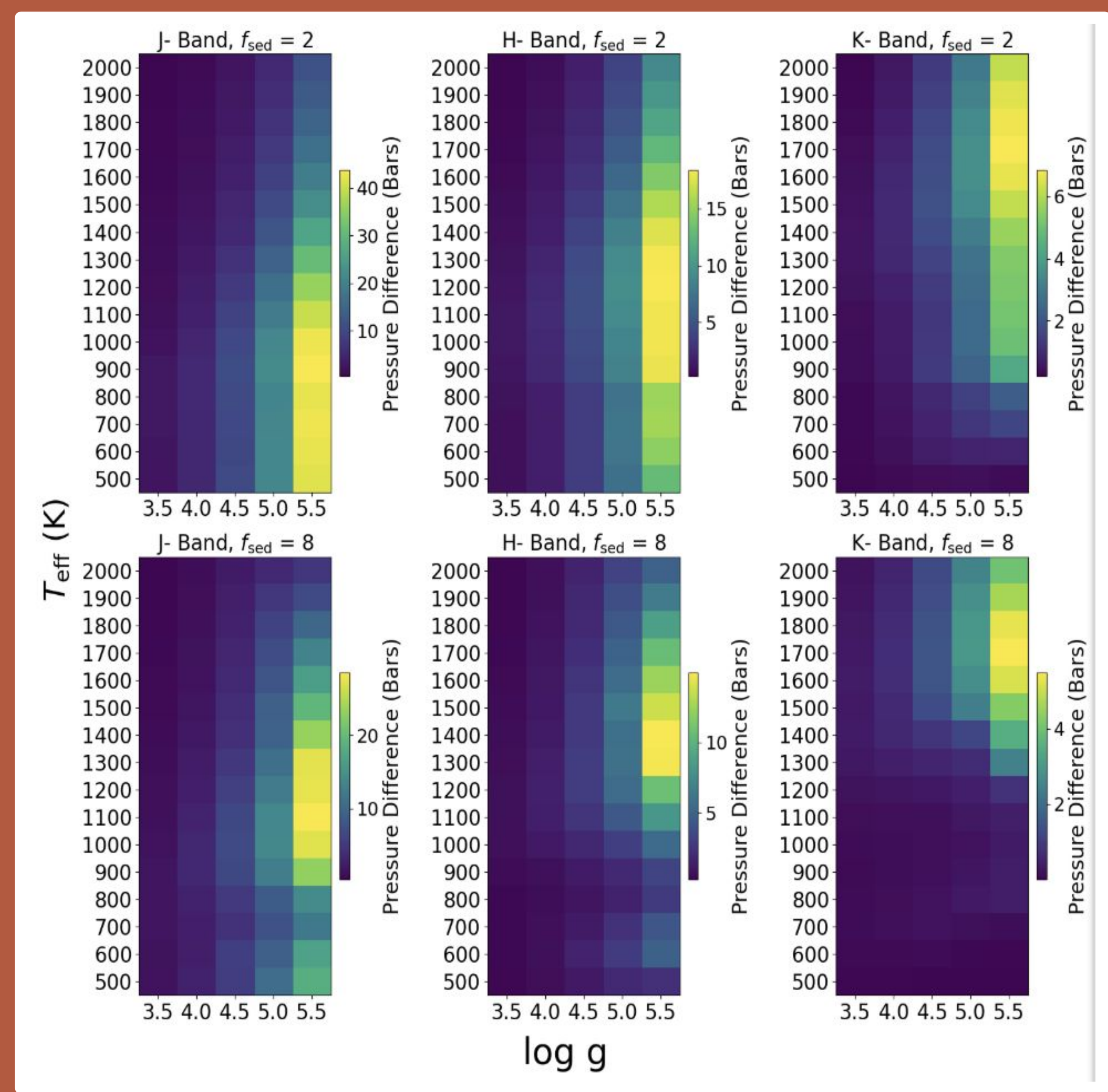


Figure 4 A heat map comparing the average pressures probed difference in the J, H, and K at an f_{sed} = 2 and f_{sed} = 8 (the former being more optically thick).

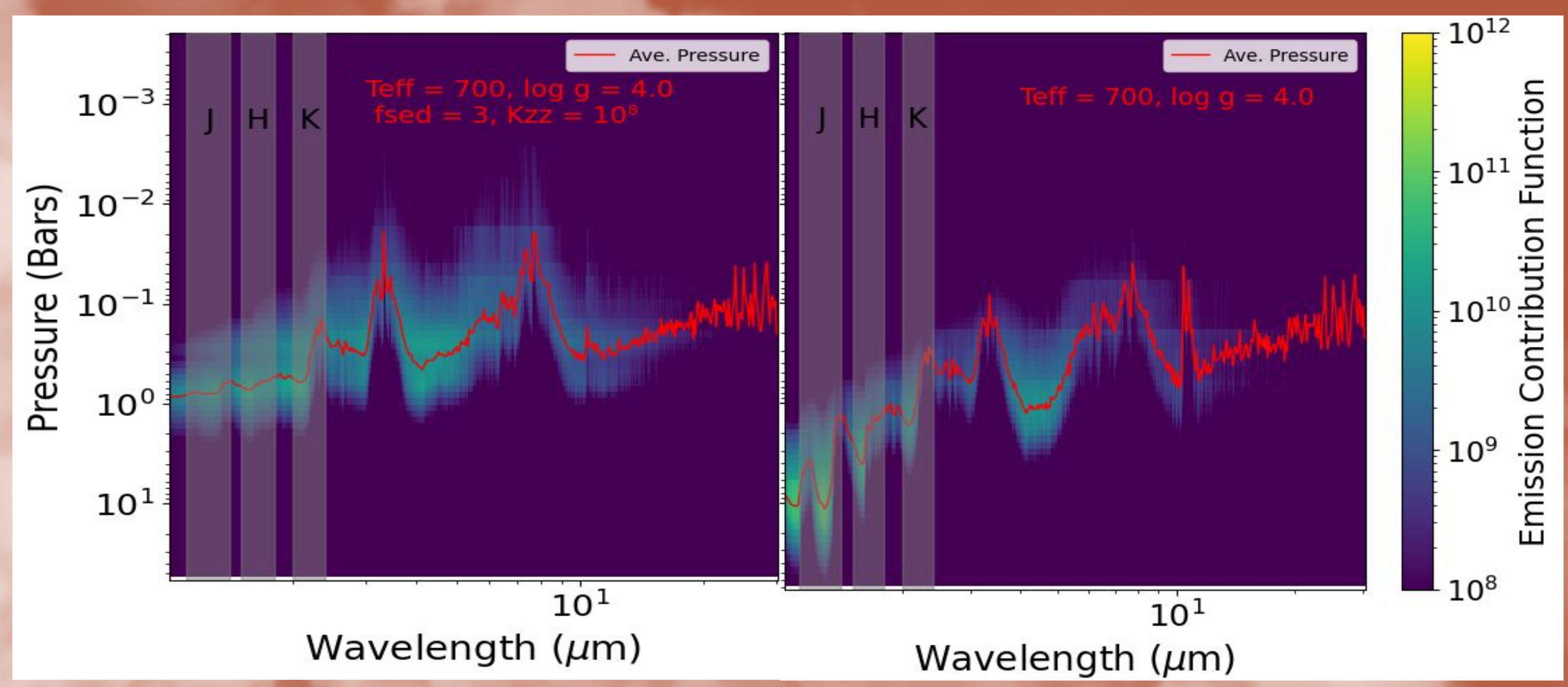


Figure 5 Full contribution functions for a cloudy(left) and cloud-free(right) model at an Teff of 700K and a log g of 4.0 . The average pressure probed at each wavelength is shown in red.

What's Next

- Finalize the GUI for the contribution functions.
- Release the tool for community use.
- Map archival observations using our tool.

References/ Acknowledgments

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