Quenching-driven equatorial depletion and limb asymmetries in WASP-96b's atmosphere

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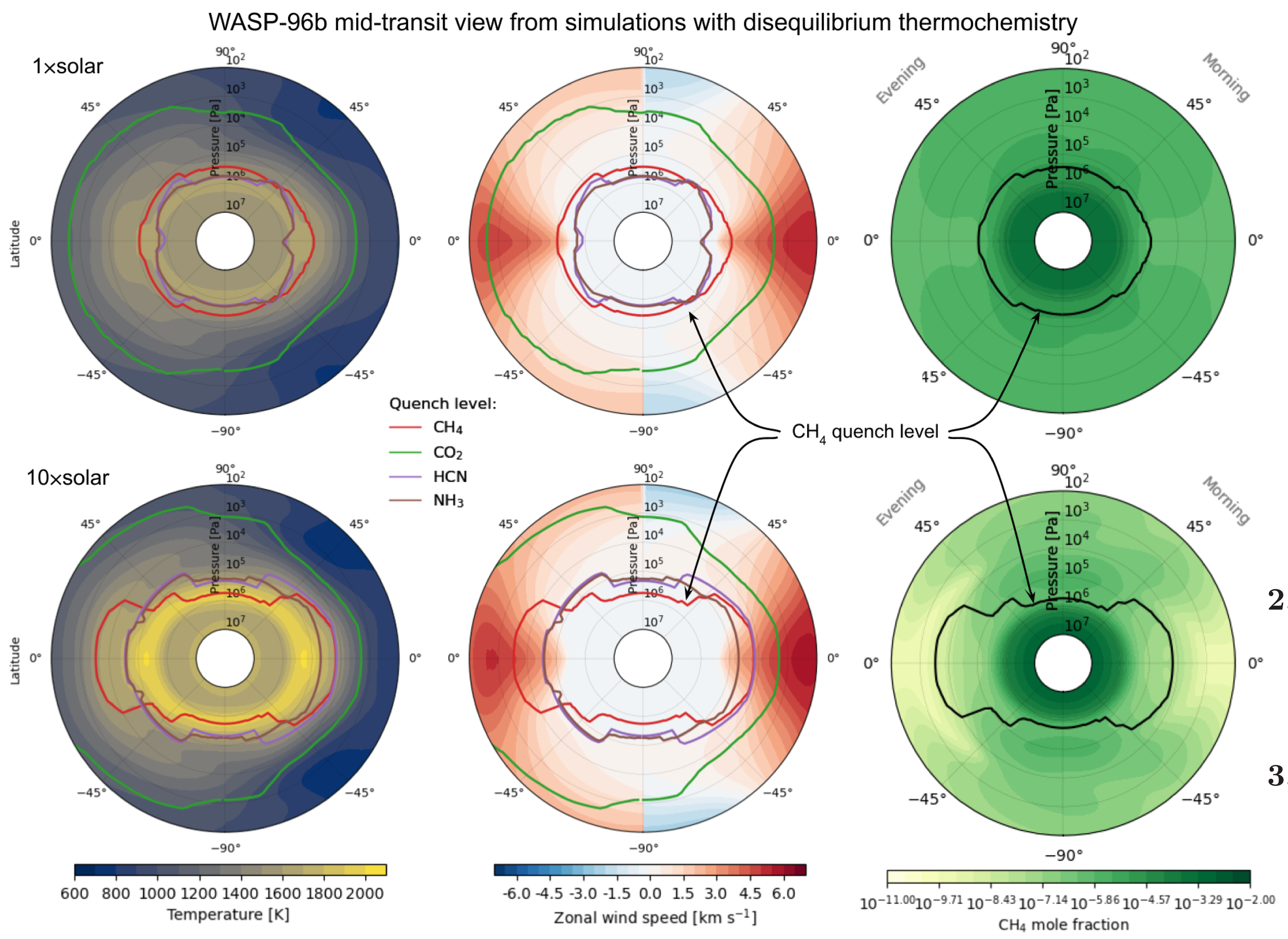
What is quenching?

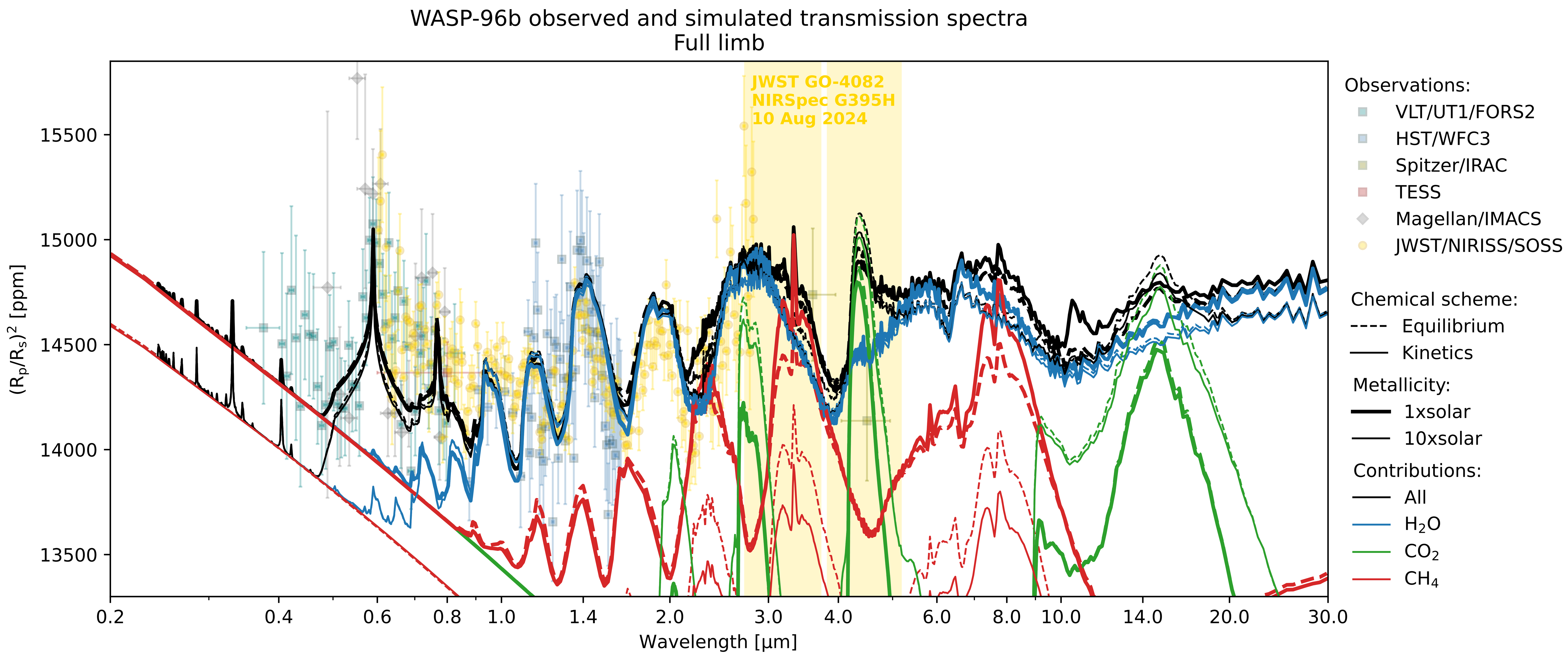
- **Transport-induced** quenching **is a process that determines the boundary between** the part of the atmosphere at **chemical equilibrium** and the part of the atmosphere at **thermochemical disequilibrium**. The location of this boundary, the **quench level**, depends on the dynamical and chemical timescales in the atmosphere, with quenching occurring when these timescales are equal.

What does our GCM predict? Quenching causes CH_4 equatorial depletion at 10×solar.



1. **Met Office Unified Model 3D GCM** setup:
   - full, non-hydrostatic equations of motion;
   - correlated-k + equivalent extinction radiative transfer (incl. H_2O, CO, CO_2, CH_4, NH_3, HCN, Li, Na, K, Rb, Cs, H_2-H_2 CIA, H_2-He CIA; H_2 and He scattering);
   - Venot+2019 C-H-O-N reduced chemical network;
   - weaker dissipation;
   - no photodissociation, no aerosols;
   - 2.5° longitude by 2° latitude and 66 vertical levels equally spaced in height (from $\sim 2 \times 10^7$ to ~ 1 Pa);
   - **WASP-96b** — a relatively "aerosol-free" hot Jupiter, 0.48 ± 0.03 M_J, 1.20 ± 0.06 R_J, $T_{equ} = 1285 \pm 40$ K, orbiting a G8 star at 0.0453 AU in 3.425 days.
2. Experiments:
   - 1× and 10×solar metallicity;
   - equilibrium and **disequilibrium thermochemistry**.
3. Temperature increase at $\sim 10^4$-10^7 Pa caused by a higher assumed atmospheric metallicity (left column), shifts the quench levels to lower pressures, closer to the region of equatorial jet (middle column), and causes an **equatorial depletion of CH_4 (bottom right), NH_3 and HCN.**

Does quenching impact WASP-96b's simulated transmission spectra? Yes.



4. **The ∼3-5 μm region is the most powerful region for distinguishing atmospheres at chemical equilibrium from those with upper layers at thermochemical disequilibrium, and uniquely identifying their metallicity.**

5. In that region the shape of transmission spectra (incl. evening-morning limb asymmetries) is different between our 1× and 10× solar simulations with equilibrium and disequilibrium thermochemistry due to the **difference in H_2O abundance and quenching behaviour of CO_2 and CH_4.**

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