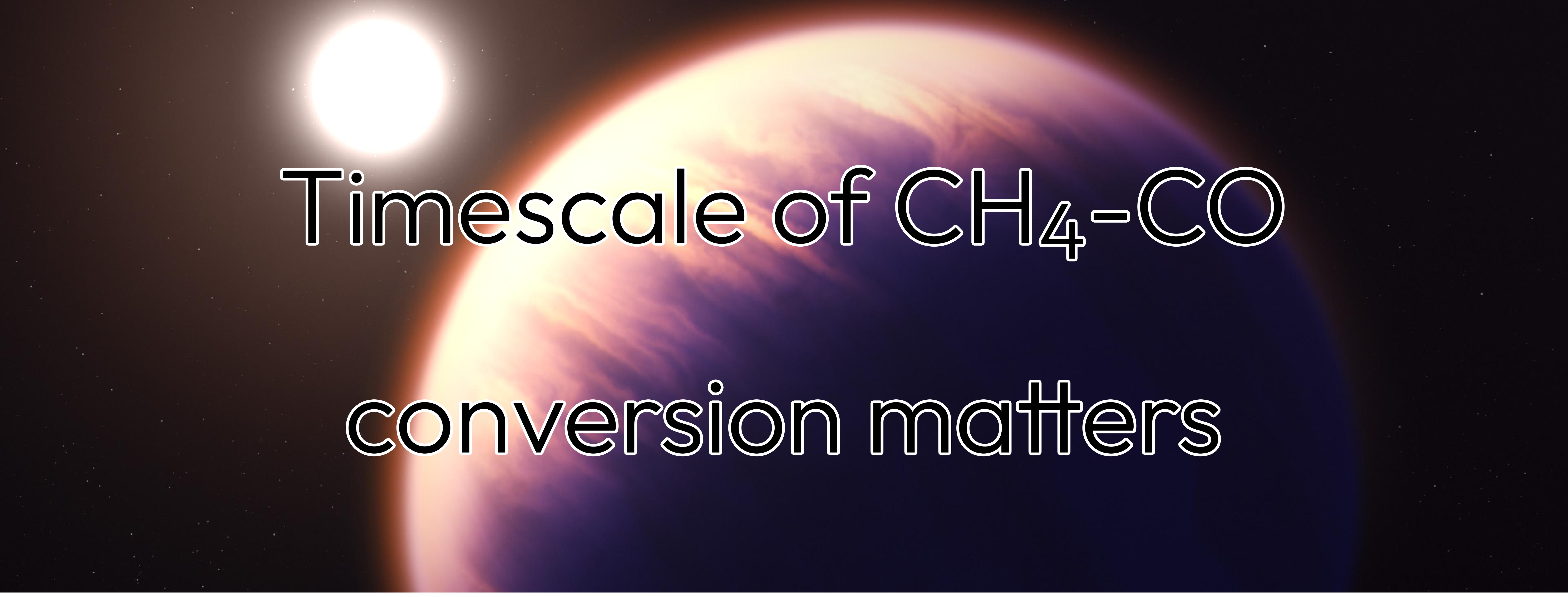

Timescale of CH_4-CO conversion matters

CH_4-CO conversion pathways in hot Jupiter atmospheres

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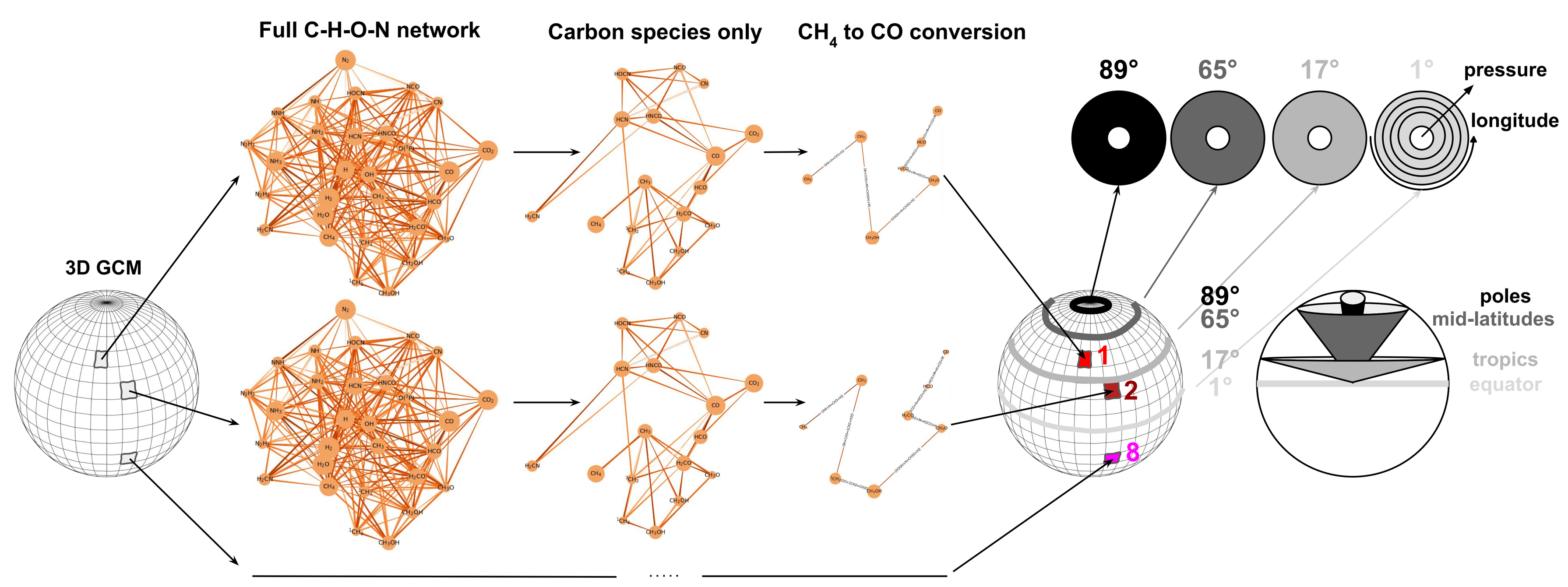
What motivated us?

- CH_4 and CO – major C-bearing chemical species in hot Jupiter atmospheres.
- CH_4 can be kinetically converted to CO and back.
- There are many CH_4-CO conversion pathways.
- The pathway that dominates at pressures where CH_4 and CO are interconverted slower than transported by the wind is critical for **quenching**.
- What are the main CH_4-CO conversion pathways on hot Jupiters?
- Do these pathways change around the planet?

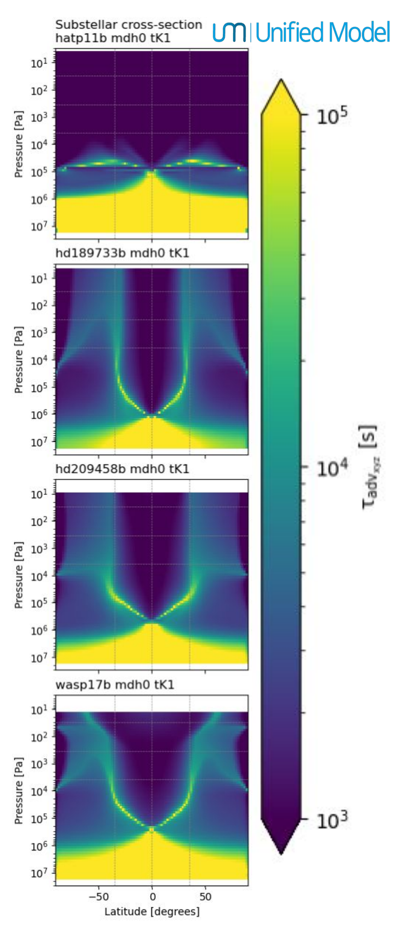
How did we model this?

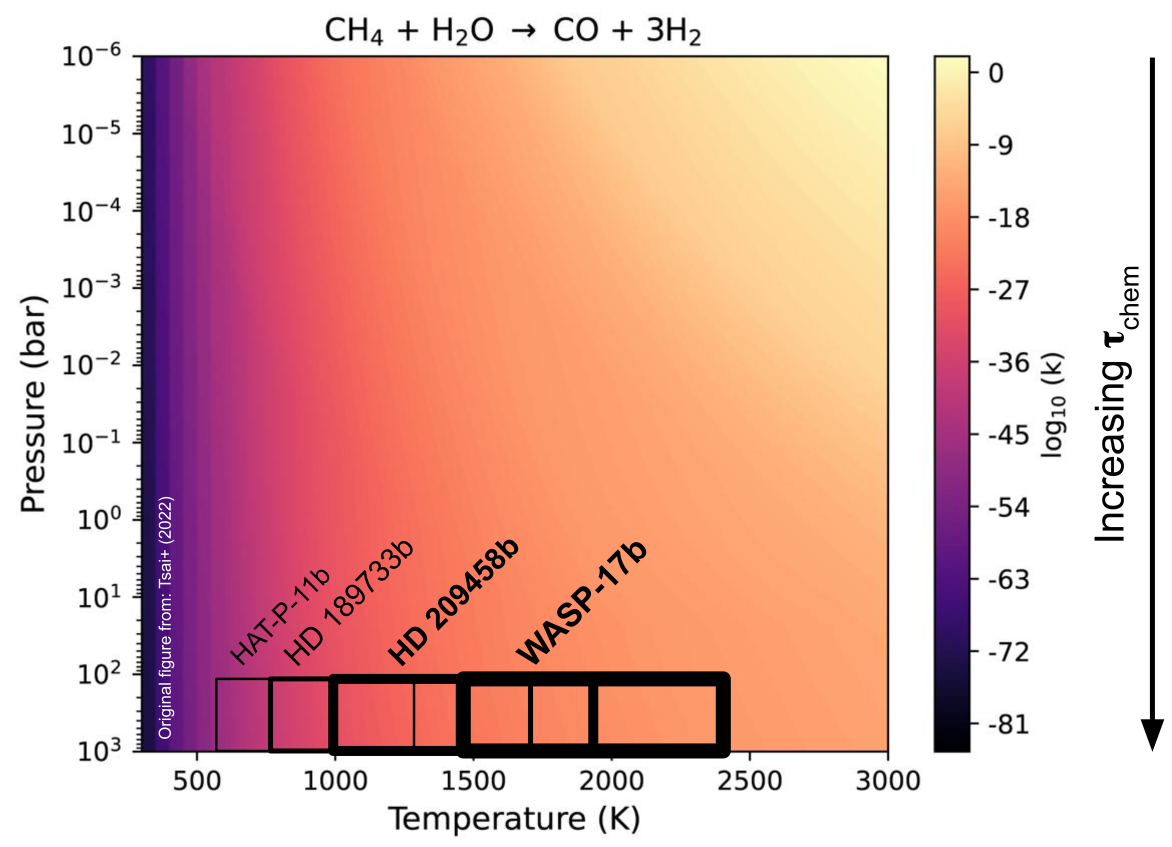
- Unified Model, Met Office's **3D general circulation model (GCM)**
- Fluid dynamics coupled with correlated-k radiative transfer and **chemical kinetics**
- Solar metallicity, aerosol-free
- Planets: HAT-P-11b, HD 189733b, HD 209458b, WASP-17b



Transport vs chemistry

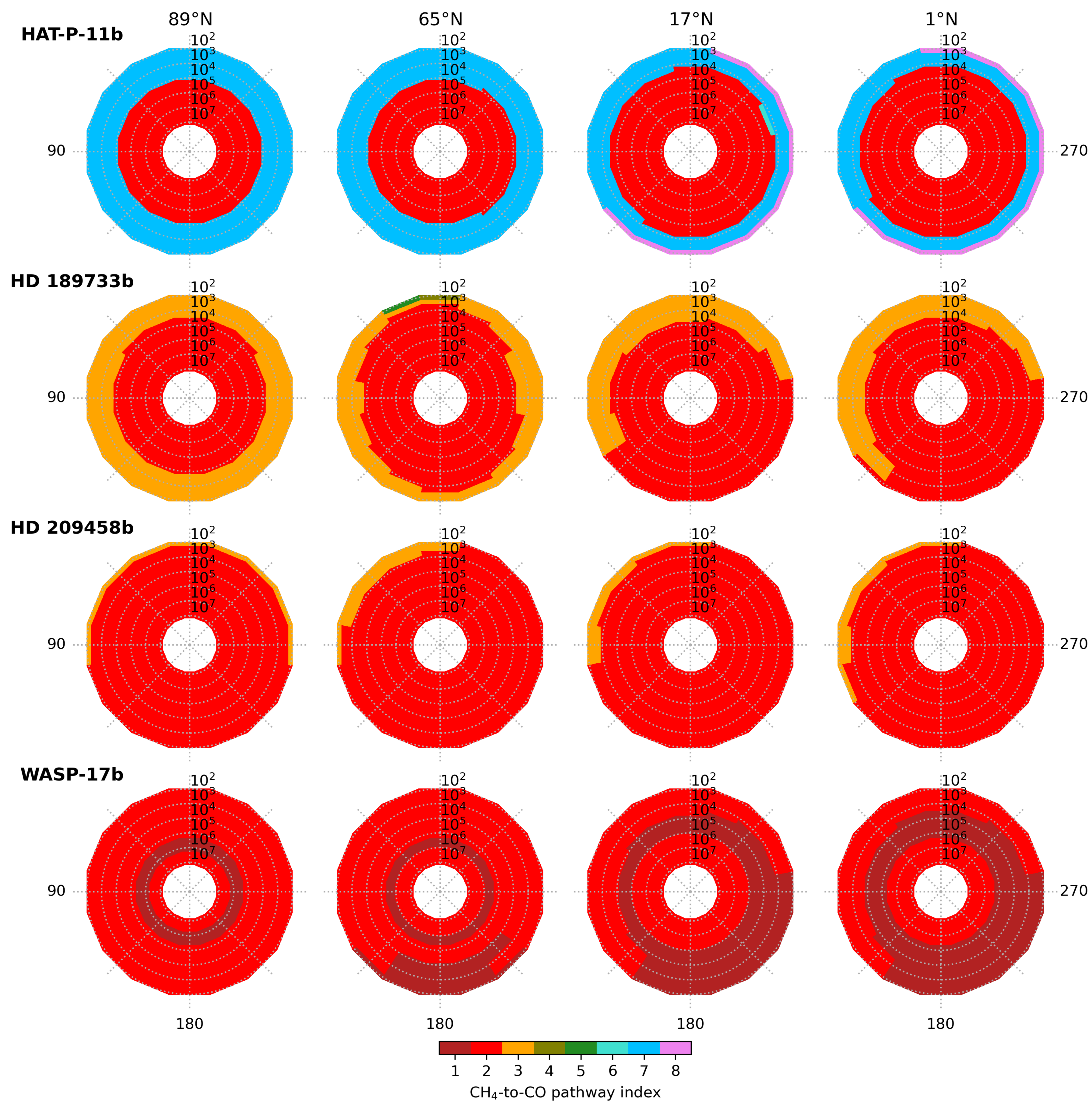
- Left: **transport timescale** from our GCM.
- Right: **CH_4-CO conversion timescale** from Tsai+2022, A&A (for illustration only).





What did we find?

- The same pathway operates at the CH_4 quench level.
- Different pathways at lower pressures.



1
$CH_4+H \rightarrow CH_3+H_2$
$O(^3P)+CH_3 \rightarrow H_2CO+H$
$H_2CO+H \rightarrow HCO+H_2$
$HCO+M \rightarrow H+CO+M$

2
$CH_4+H \rightarrow CH_3+H_2$
$OH+CH_3(+M) \rightarrow CH_3OH(+M)$
$CH_3OH+H \rightarrow CH_3O+H_2$
$CH_3O+M \rightarrow H_2CO+H+M$
$H_2CO+H \rightarrow HCO+H_2$
$HCO+M \rightarrow H+CO+M$

3
$CH_4+H \rightarrow CH_3+H_2$
$OH+CH_3 \rightarrow {}^1CH_2+H_2O$
$H_2O+{}^1CH_2 \rightarrow CH_3OH$
$CH_3OH+H \rightarrow CH_3O+H_2$
$CH_3O+M \rightarrow H_2CO+H+M$
$H_2CO+H \rightarrow HCO+H_2$
$HCO+M \rightarrow H+CO+M$

4
$CH_4+H \rightarrow CH_3+H_2$
$OH+CH_3 \rightarrow {}^1CH_2+H_2O$
${}^1CH_2+M \rightarrow {}^3CH_2+M$
$CO_2+{}^3CH_2 \rightarrow H_2CO+CO$
$H_2CO+H \rightarrow HCO+H_2$
$HCO+M \rightarrow H+CO+M$

5
$CH_4+H \rightarrow CH_3+H_2$
$OH+CH_3 \rightarrow {}^1CH_2+H_2O$
${}^1CH_2+M \rightarrow {}^3CH_2+M$
$CO_2+{}^3CH_2 \rightarrow H_2CO+CO$
$H_2CO+H \rightarrow HCO+H_2$
$HCO+H \rightarrow H_2+CO$

6
$CH_4+H \rightarrow CH_3+H_2$
$OH+CH_3(+M) \rightarrow CH_3OH(+M)$
$CH_2OH+H_2 \leftarrow CH_3OH+H$
$CH_2OH+H \rightarrow H_2CO+H_2$
$H_2CO+H \rightarrow HCO+H_2$
$HCO+M \rightarrow H+CO+M$

7
$CH_4+H \rightarrow CH_3+H_2$
$OH+CH_3(+M) \rightarrow CH_3OH(+M)$
$CH_2OH+H_2 \leftarrow CH_3OH+H$
$CH_2OH+H \rightarrow H_2CO+H_2$
$H_2CO+H \rightarrow HCO+H_2$
$HCO+H \rightarrow H_2+CO$

8
$CH_4+H \rightarrow CH_3+H_2$
$OH+CH_3 \rightarrow {}^1CH_2+H_2O$
$H_2O+{}^1CH_2 \rightarrow CH_3OH$
$CH_2OH+H_2 \leftarrow CH_3OH+H$
$CH_2OH+H \rightarrow H_2CO+H_2$
$H_2CO+H \rightarrow HCO+H_2$
$HCO+H \rightarrow H_2+CO$

How significant is this?

- Using CH_4-CO chemical relaxation schemes is OK if no variation in CH_4-CO conversion at quench level is expected.
- But: which CH_4-CO pathway to use is important as it determines CH_4 and CO abundances at observable pressures.

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