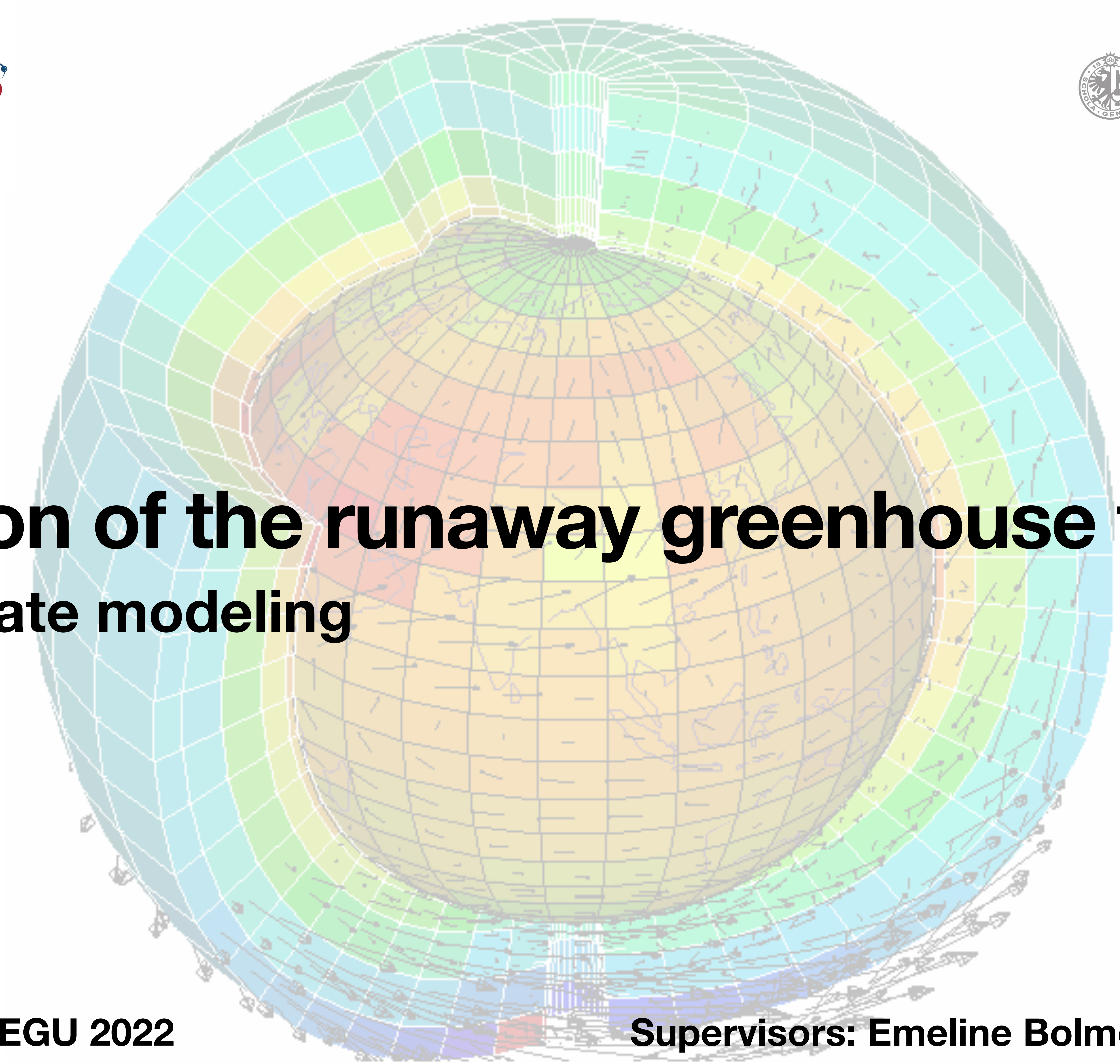


Exploration of the runaway greenhouse transition

with 3D climate modeling

This presentation participates in OSPP

EGU

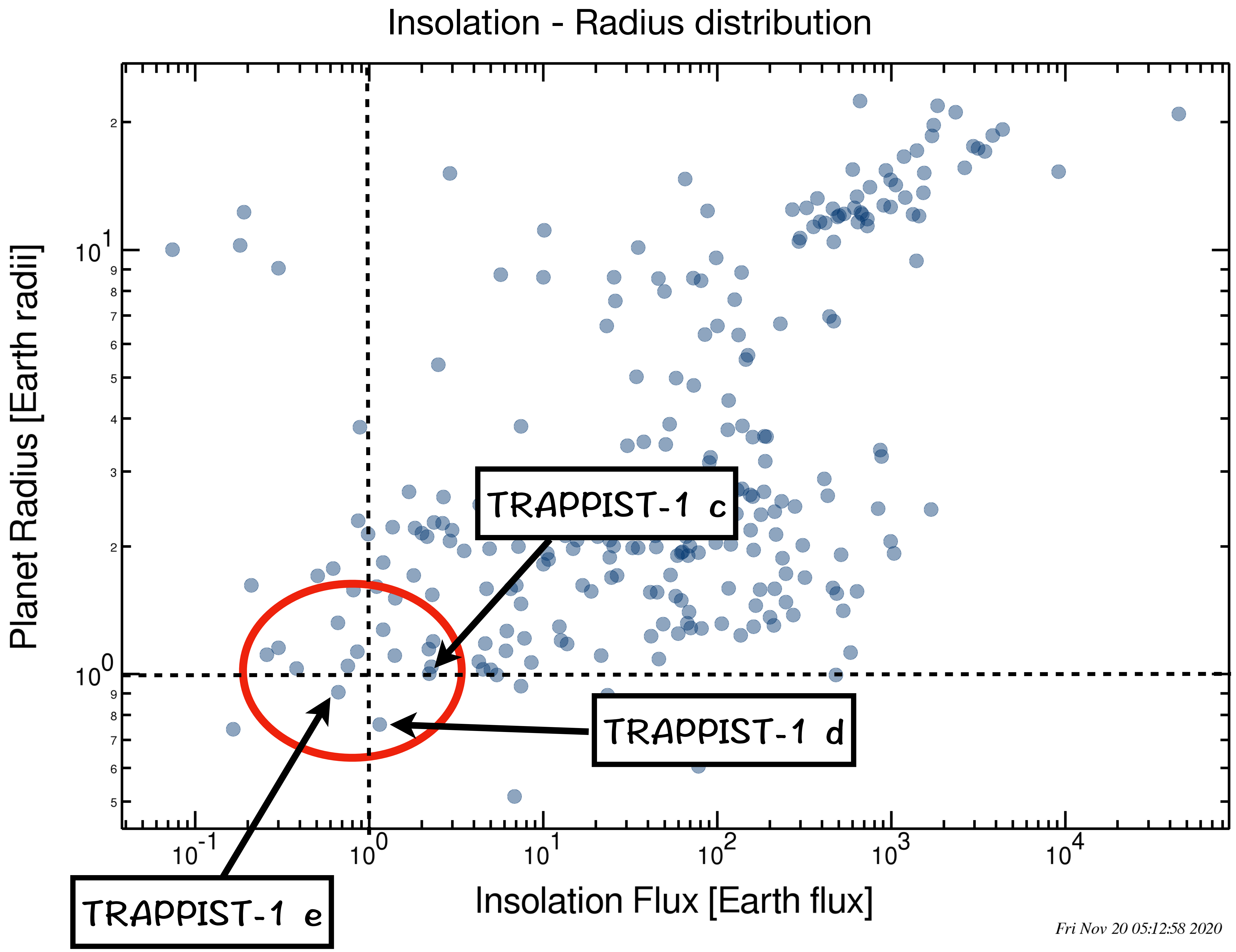
Outstanding Student & PhD candidate Presentation contest

Guillaume Chaverot - EGU 2022

Supervisors: Emeline Bolmont & Martin Turbet

Challenging targets

Small rocky planets such as Ross-128b, Trappist-1 inner planets, Gliese-411b, HD85512b, GJ-273b, GJ-411b, YZ Ceti b, etc ...



exoplanetarchive.ipac.caltech.edu

Habitability

Of small rocky exoplanets

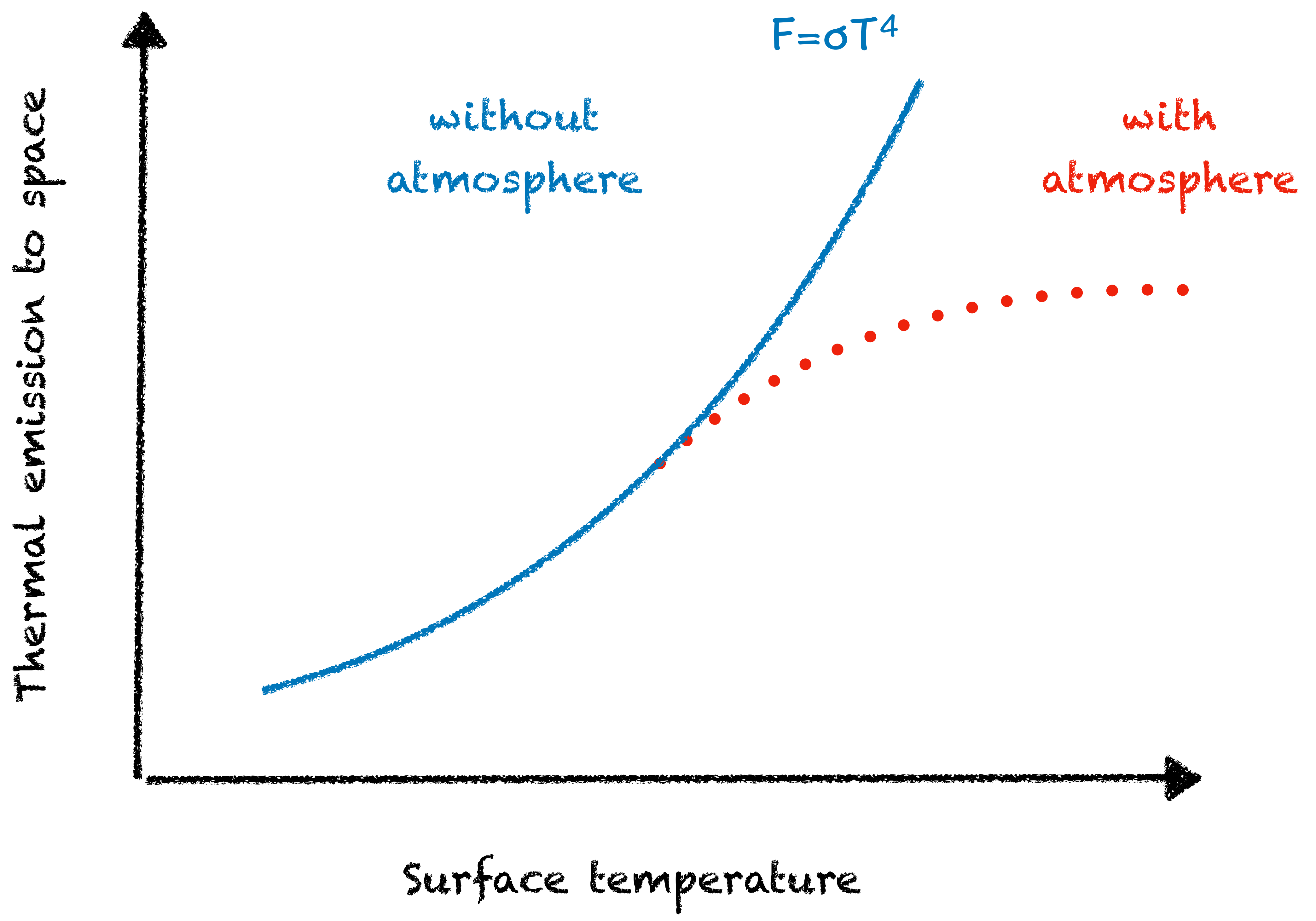
The sine qua non condition for **the emergence of life as we know it** is liquid water

-> We need to be able to estimate the **temperature** of exoplanets

Equilibrium temperature

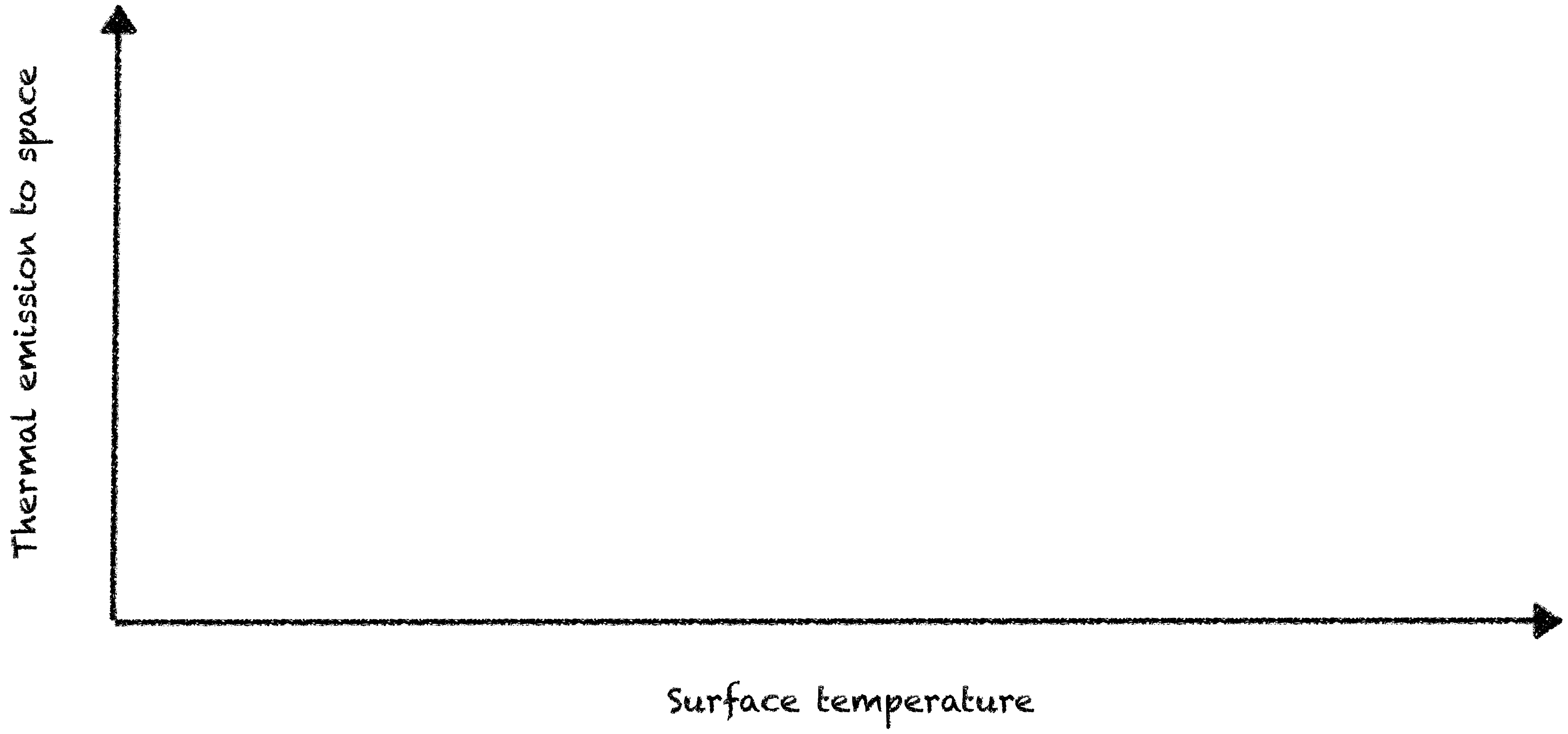
-> Absorbed flux = Thermal emission

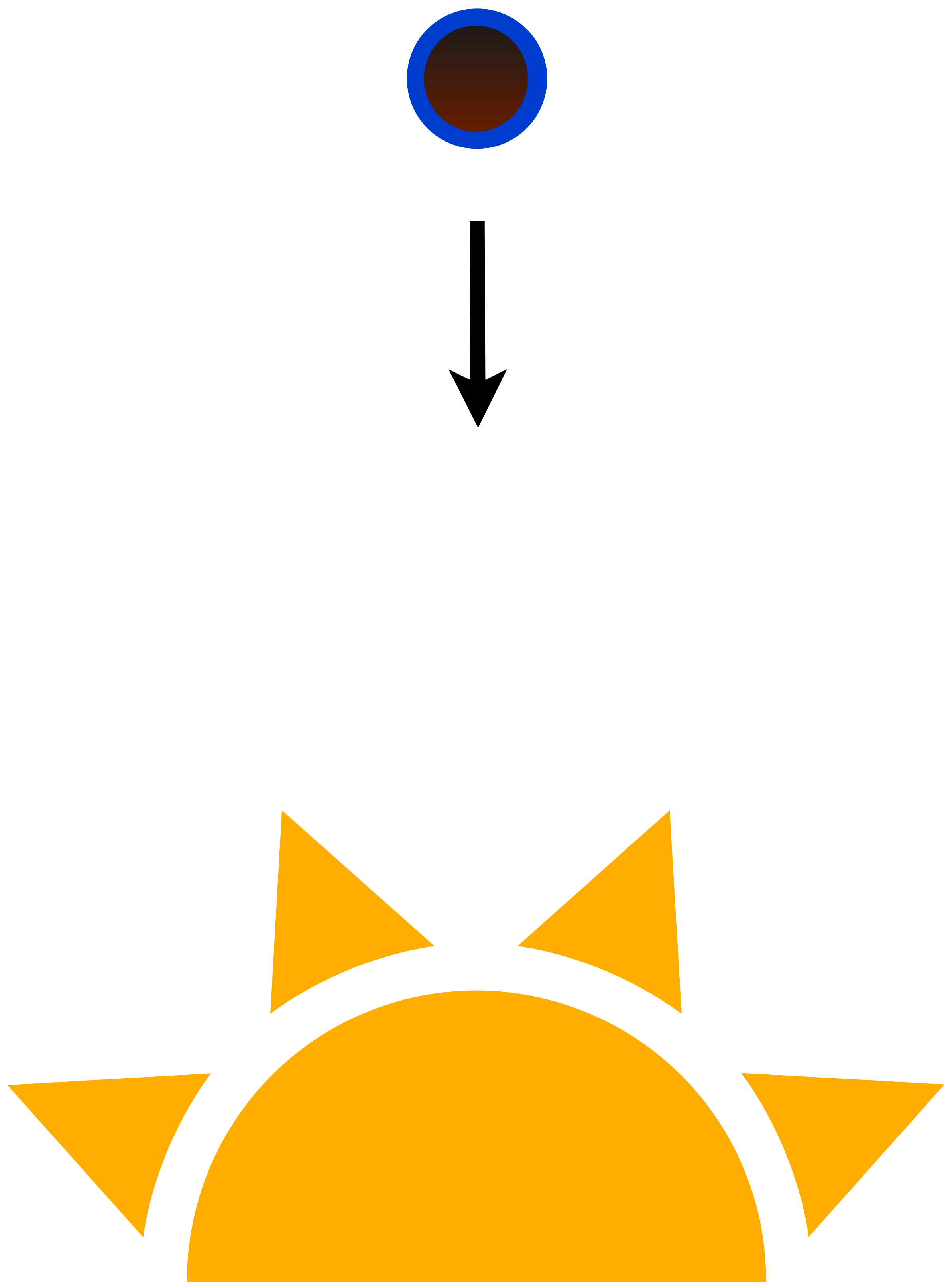
How does the thermal emission of a rocky planet with a vapor atmosphere evolve?



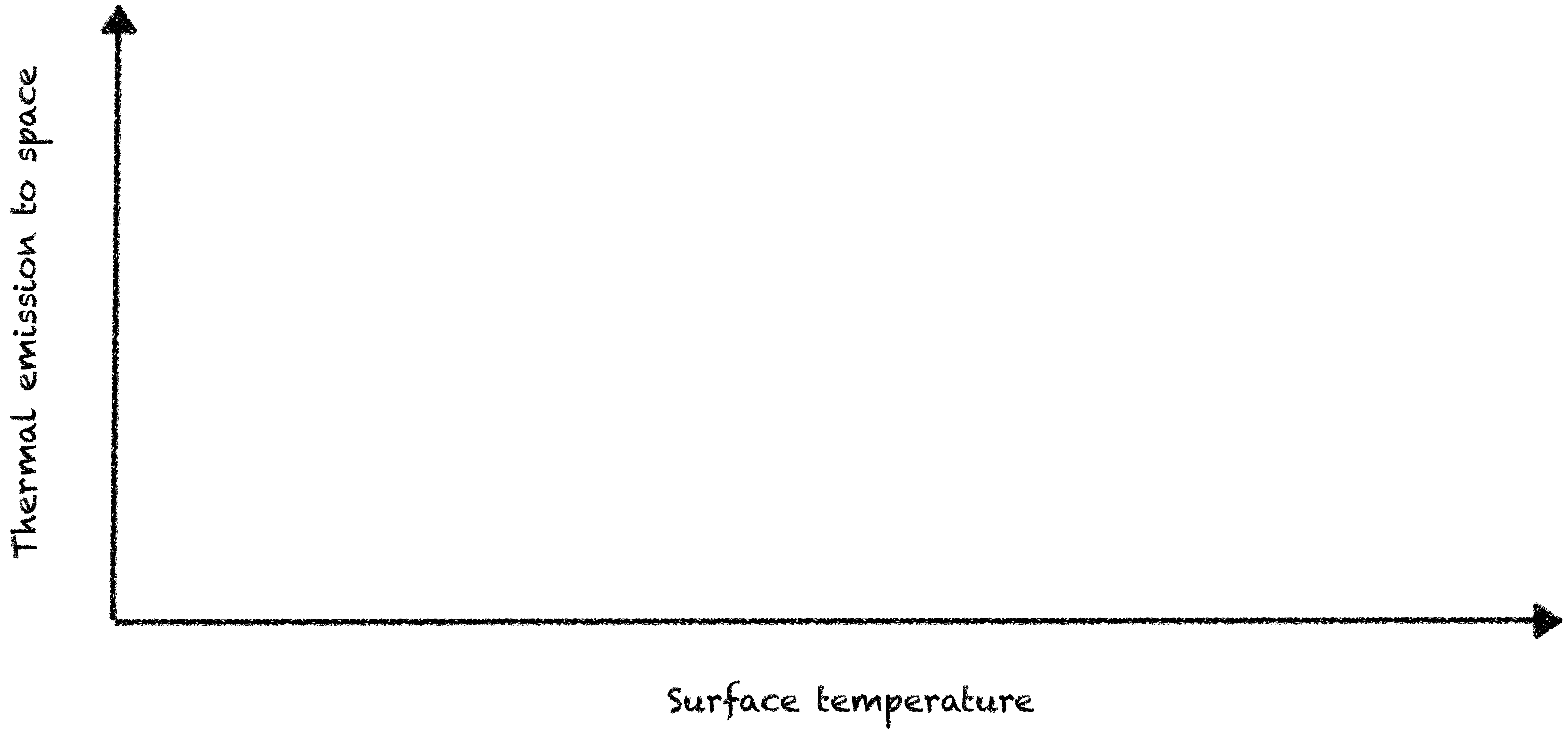
The runaway greenhouse effect

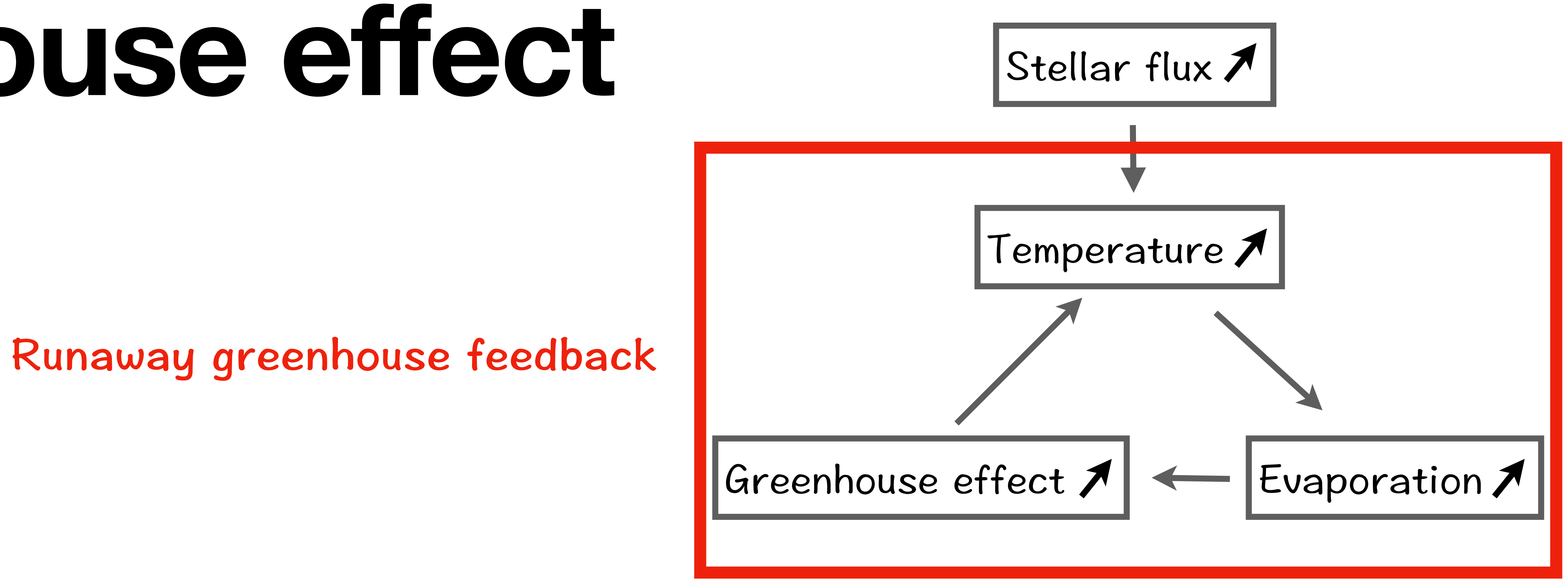
Stellar flux ↗

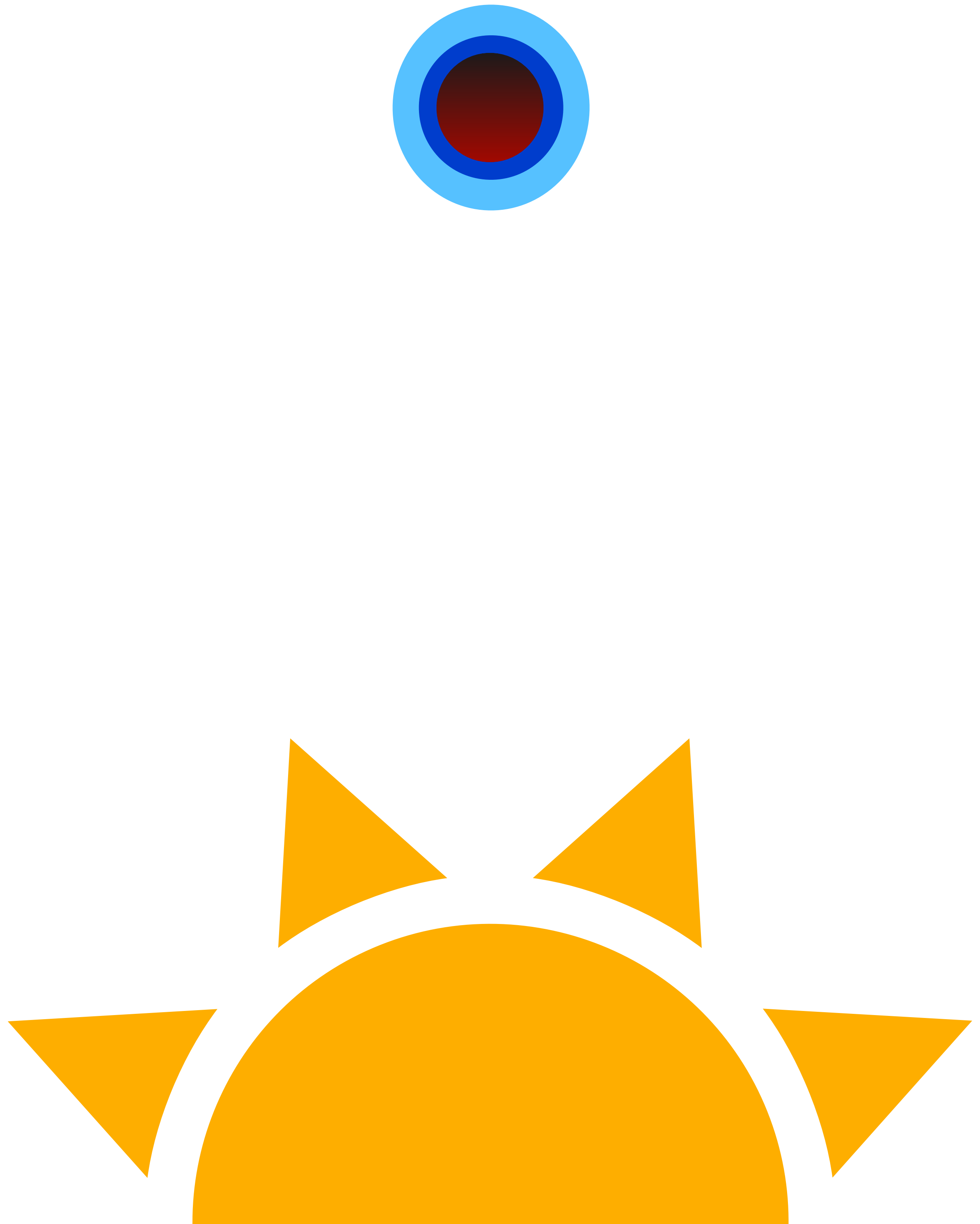




The runaway greenhouse effect

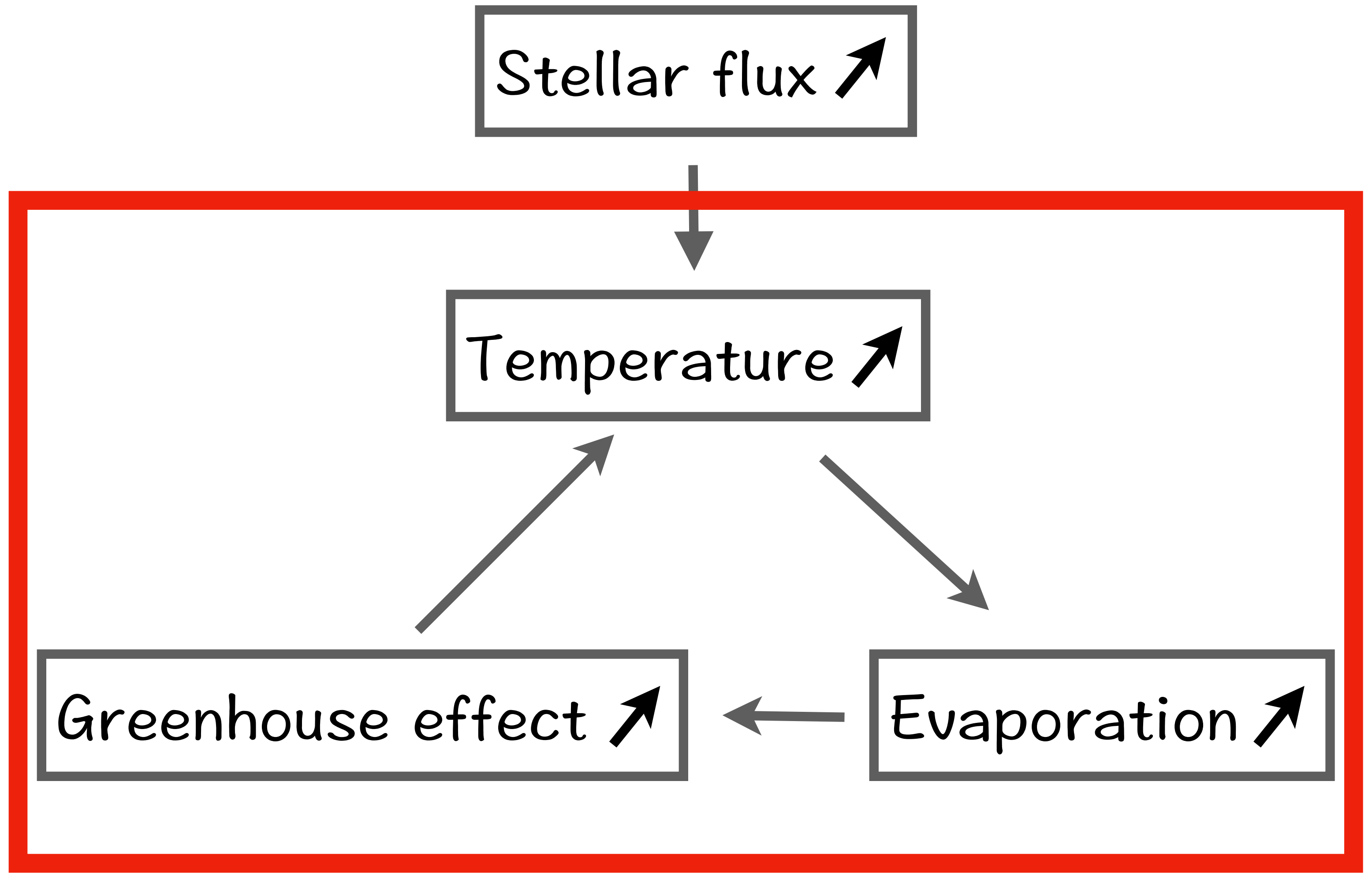


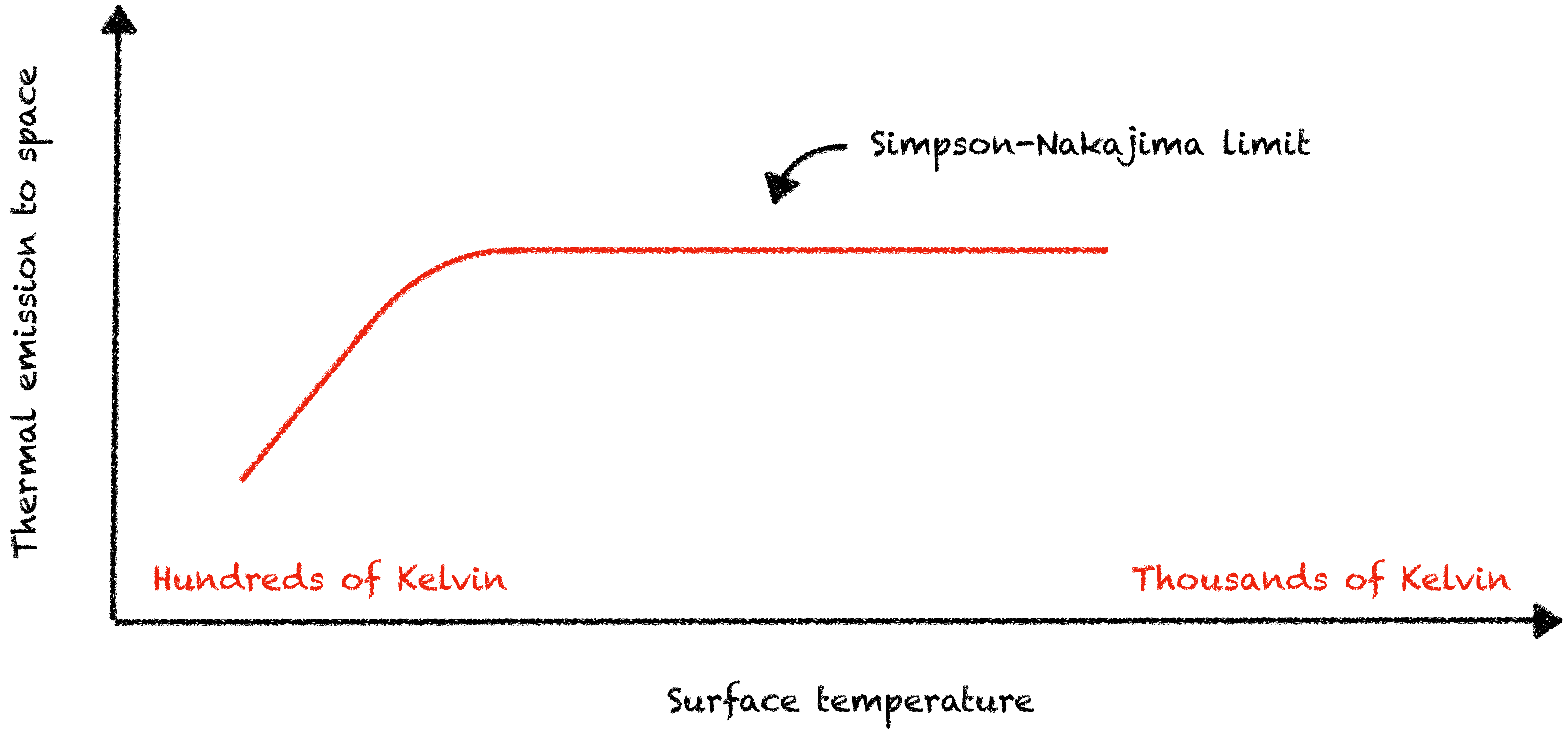


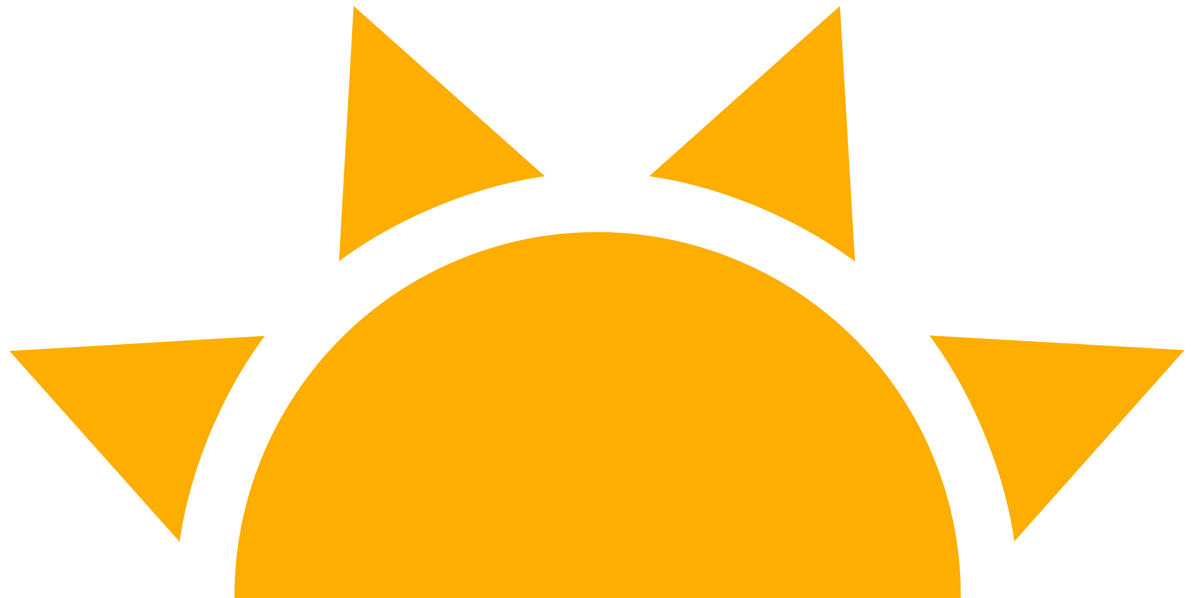


The runaway greenhouse effect

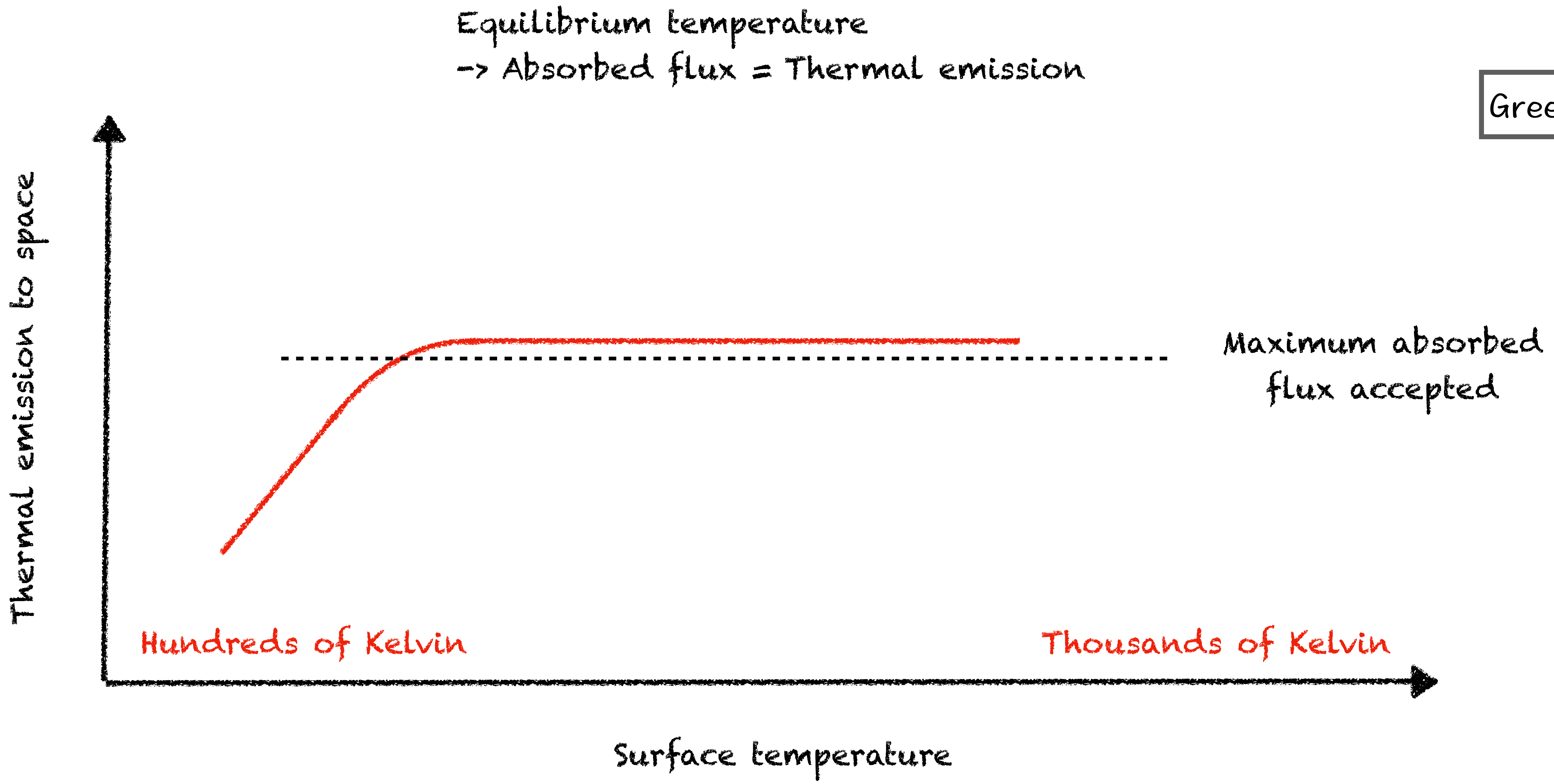
Runaway greenhouse feedback

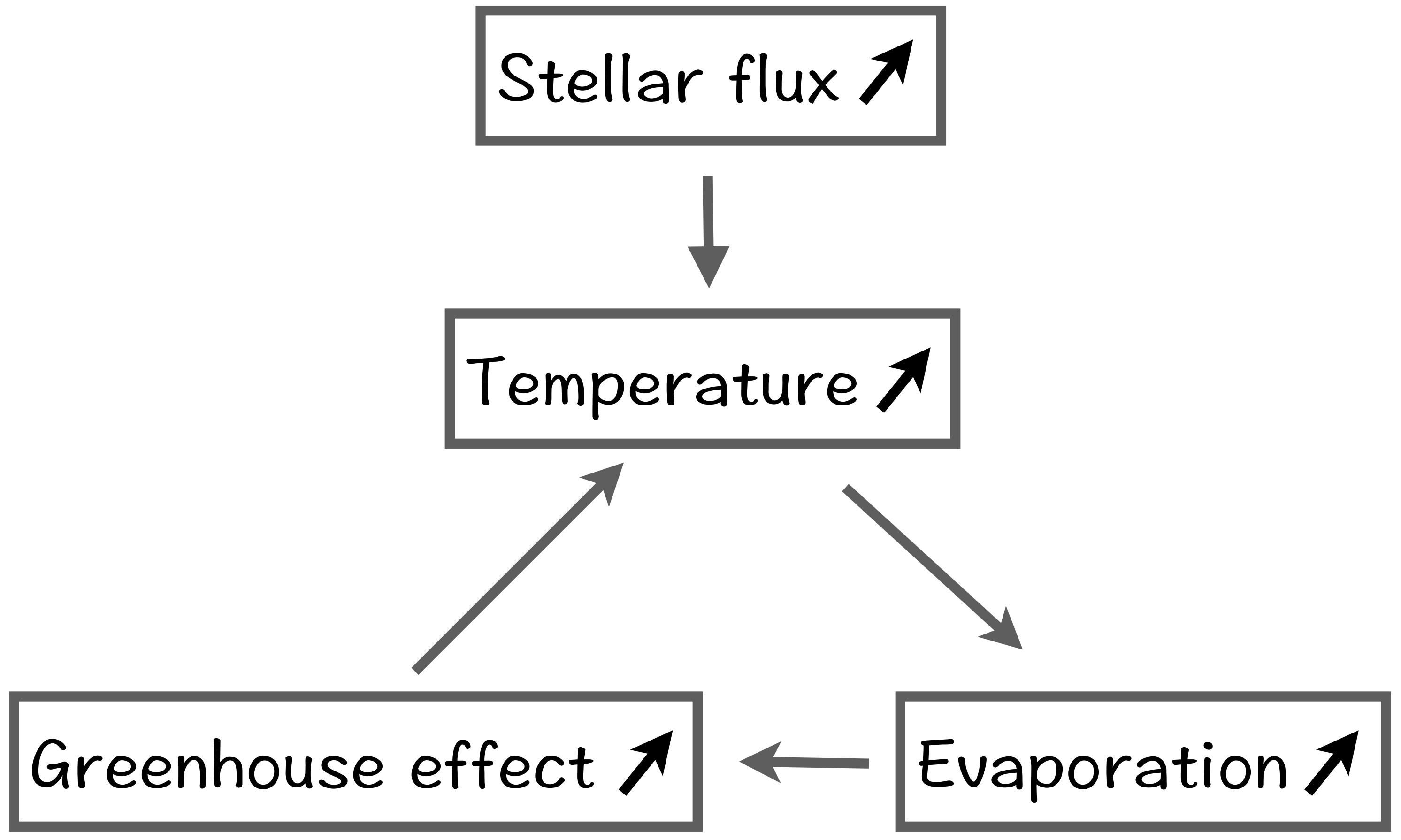


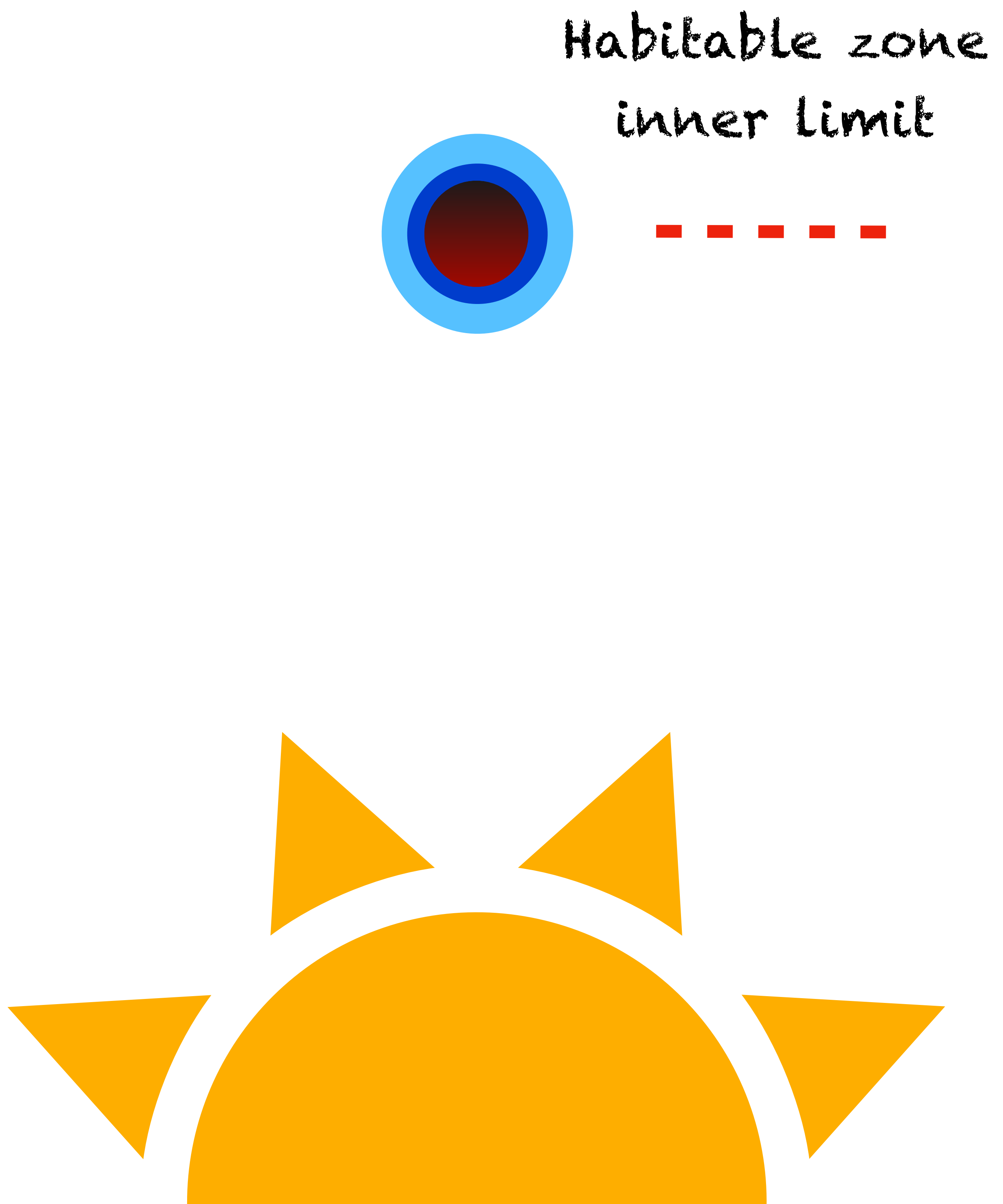




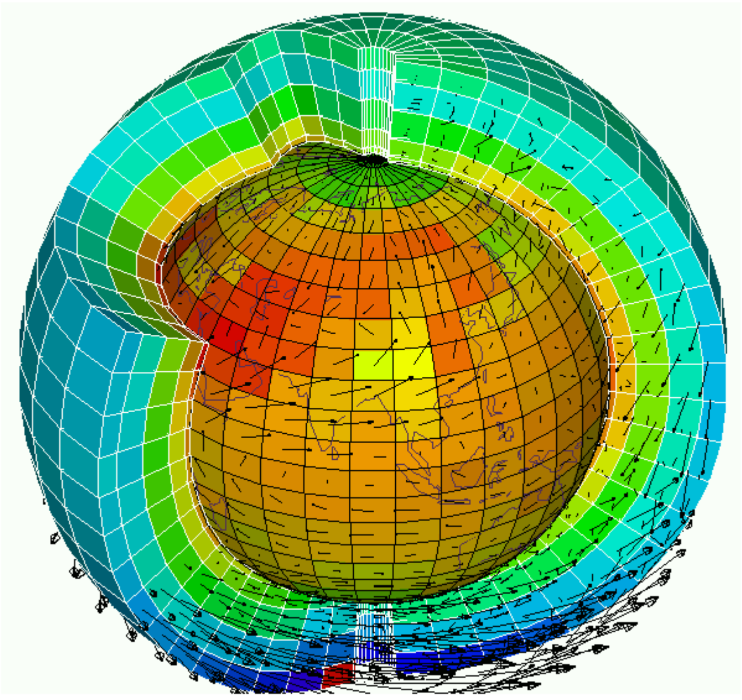
The runaway greenhouse effect



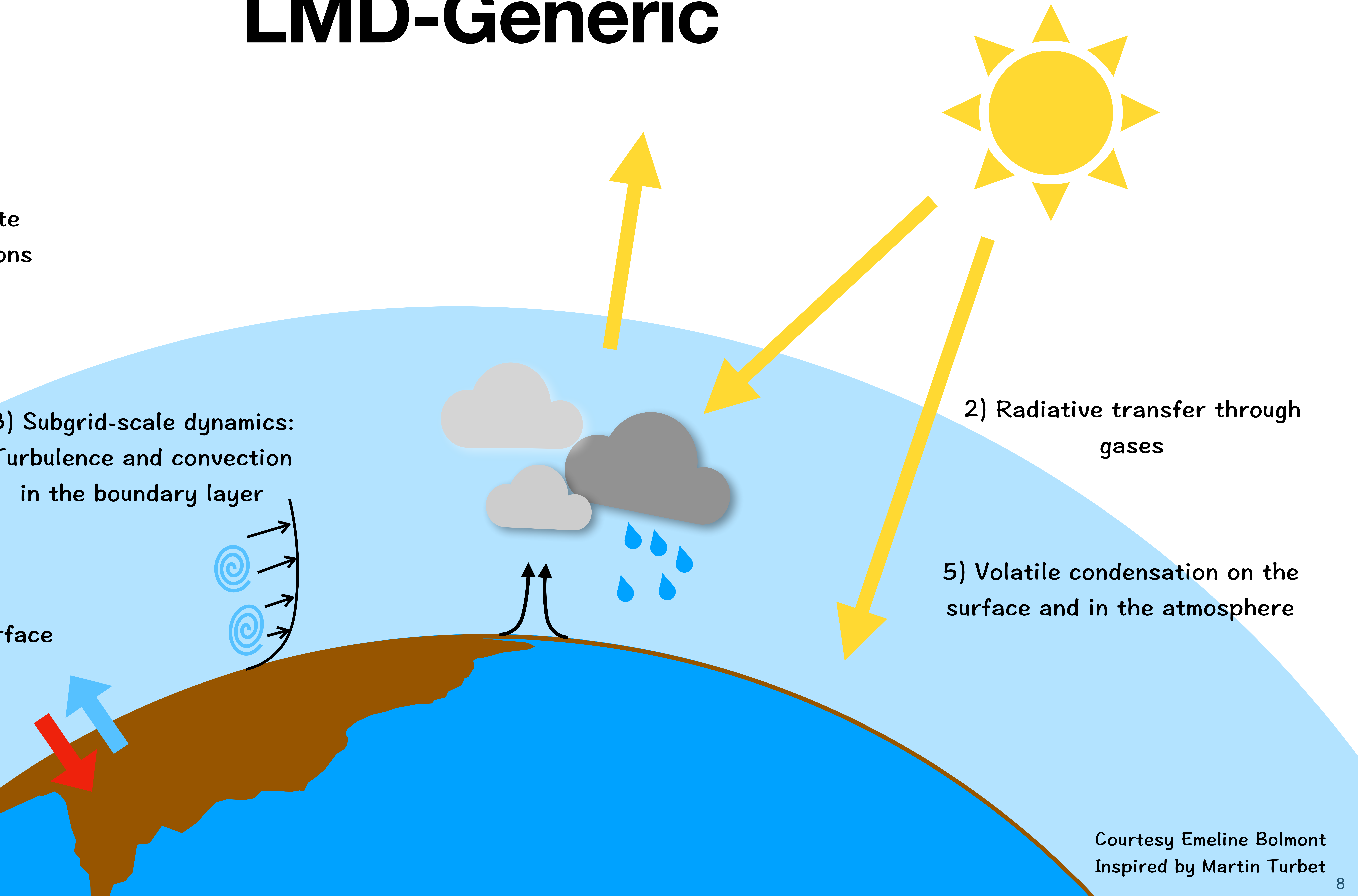




LMD-Generic



1) Dynamical Core to compute large scale atmospheric motions and transport

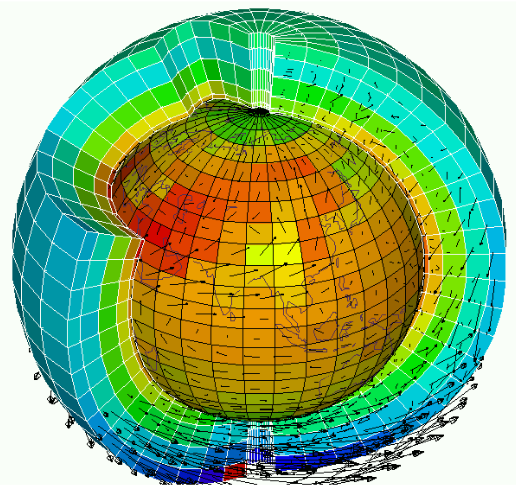


Courtesy Emeline Bolmont
Inspired by Martin Turbet

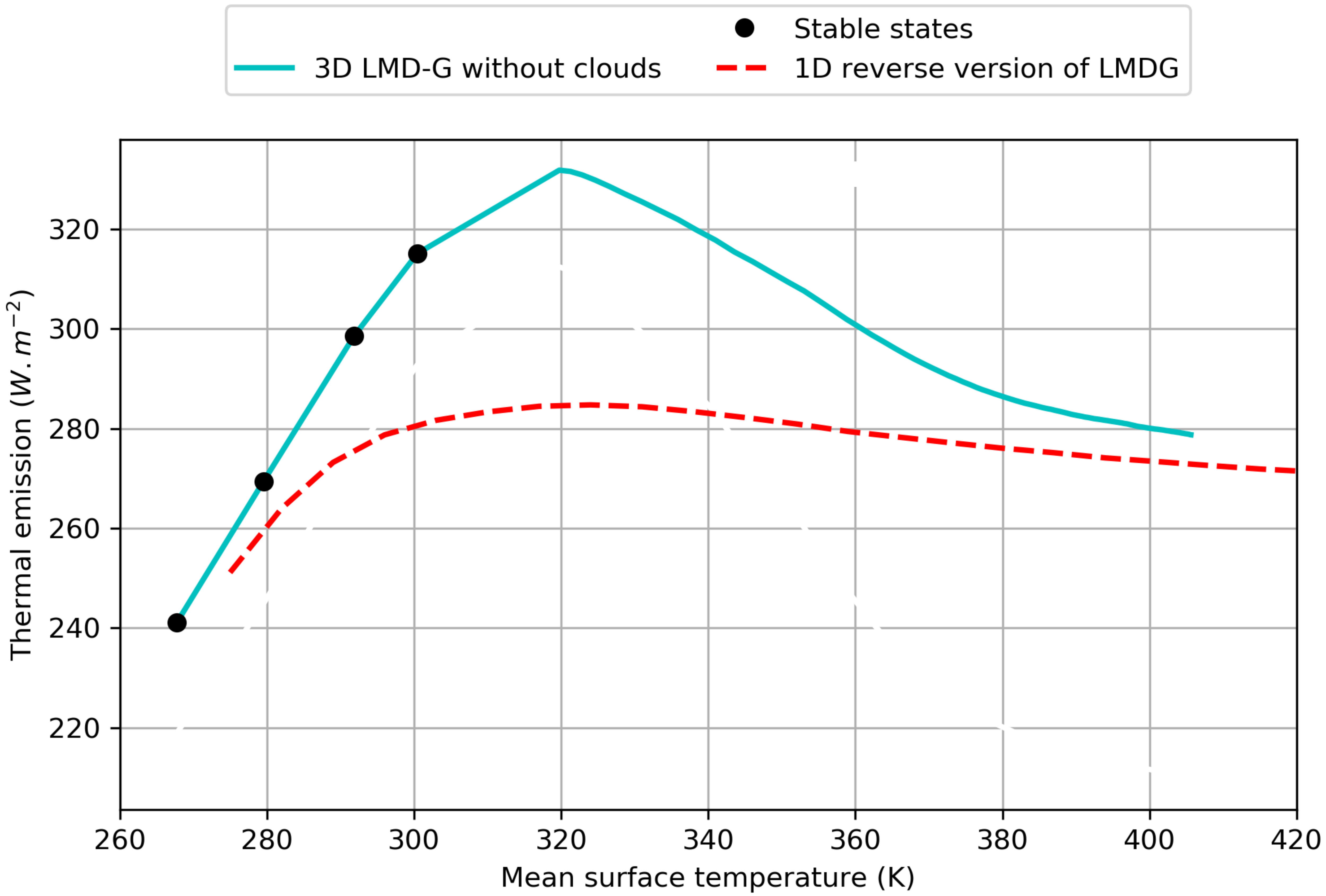
The onset

Without clouds

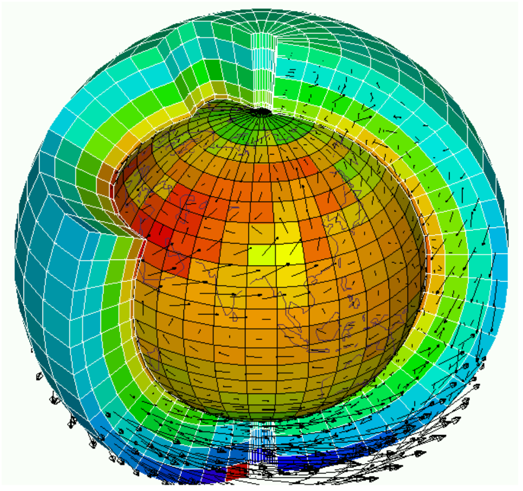
Preliminary results



Example for P_{N2}=1bar



1D simulation (red dashed curve) from Chaverot et al. (2022)

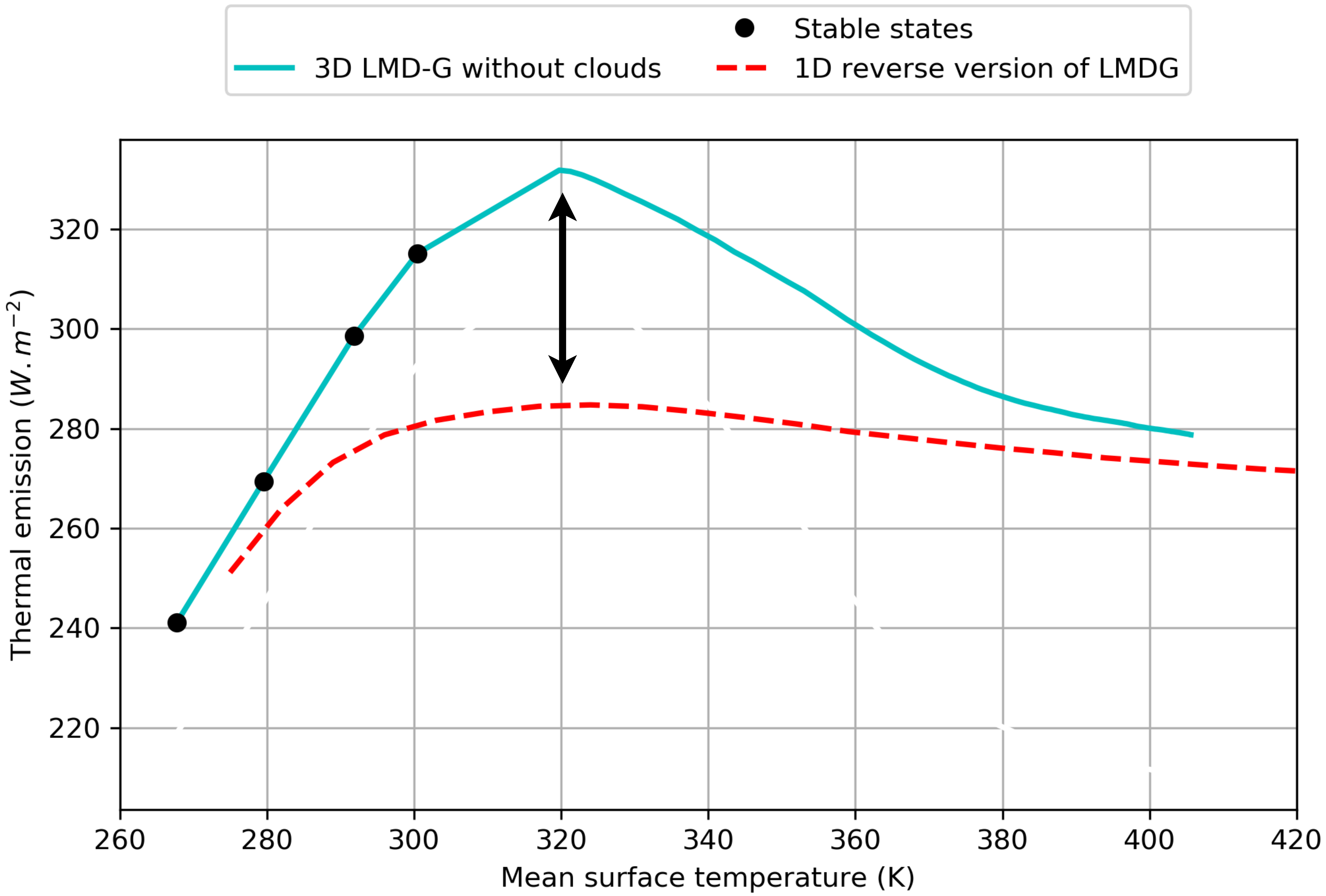


The onset

Without clouds

The maximum thermal emission is stronger in the simulation using the 3D LMD-Generic model

Example for P_{N2}=1bar



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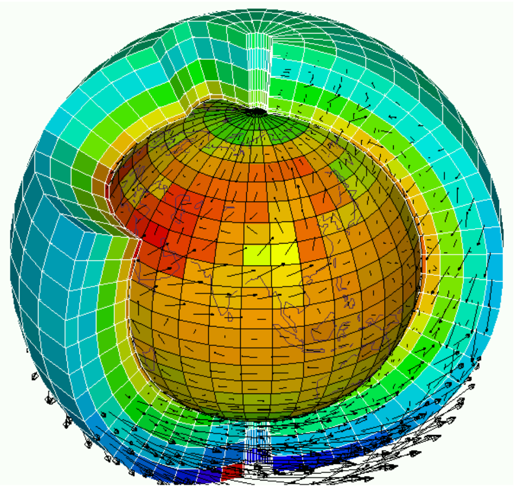
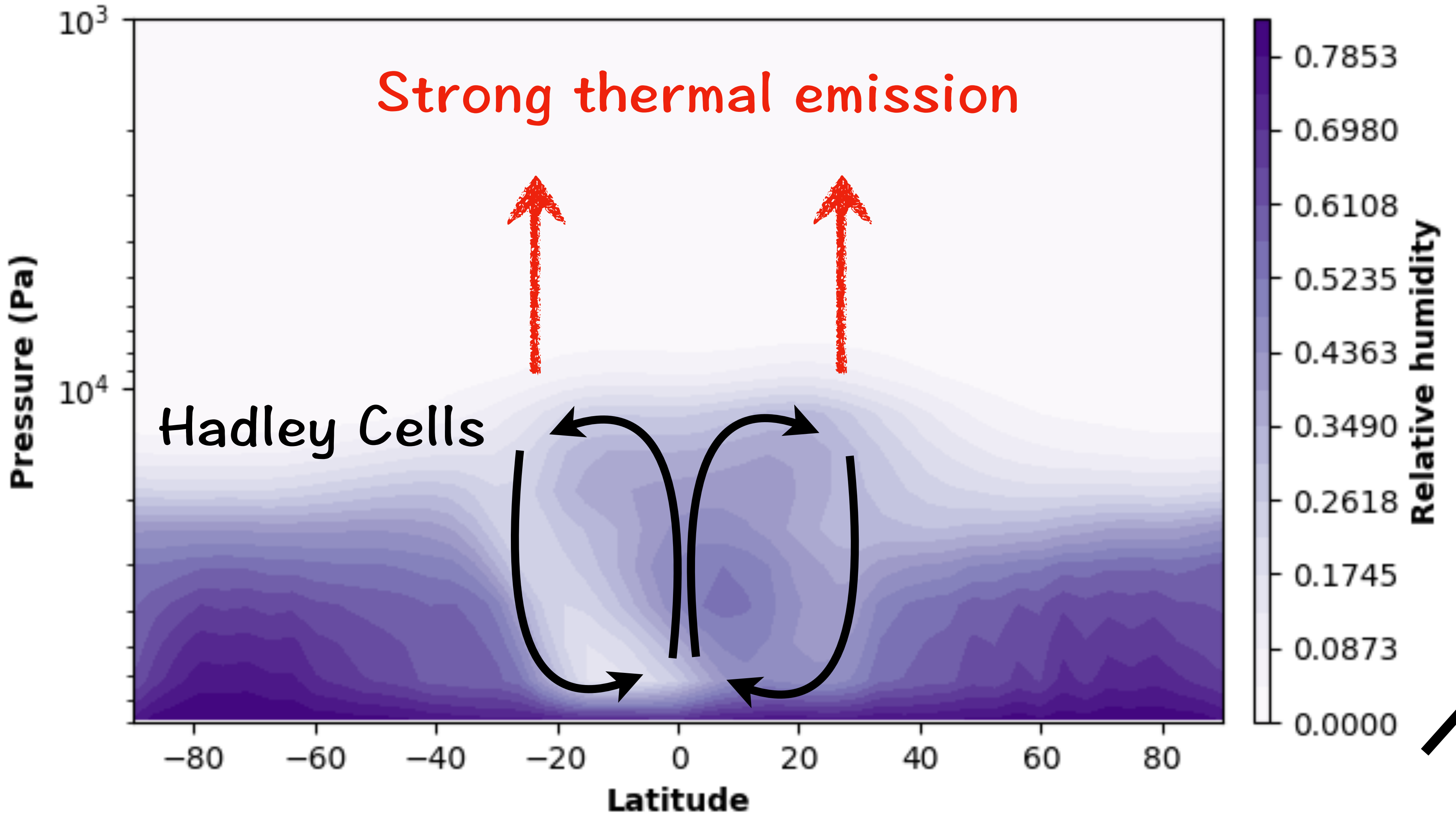


The onset

The dynamics

The maximum thermal emission is stronger in the simulation using the 3D LMD-Generic model

- The **dynamics** reduces the relative humidity (RH) thus the thermal emission increases (Leconte et al. 2013)



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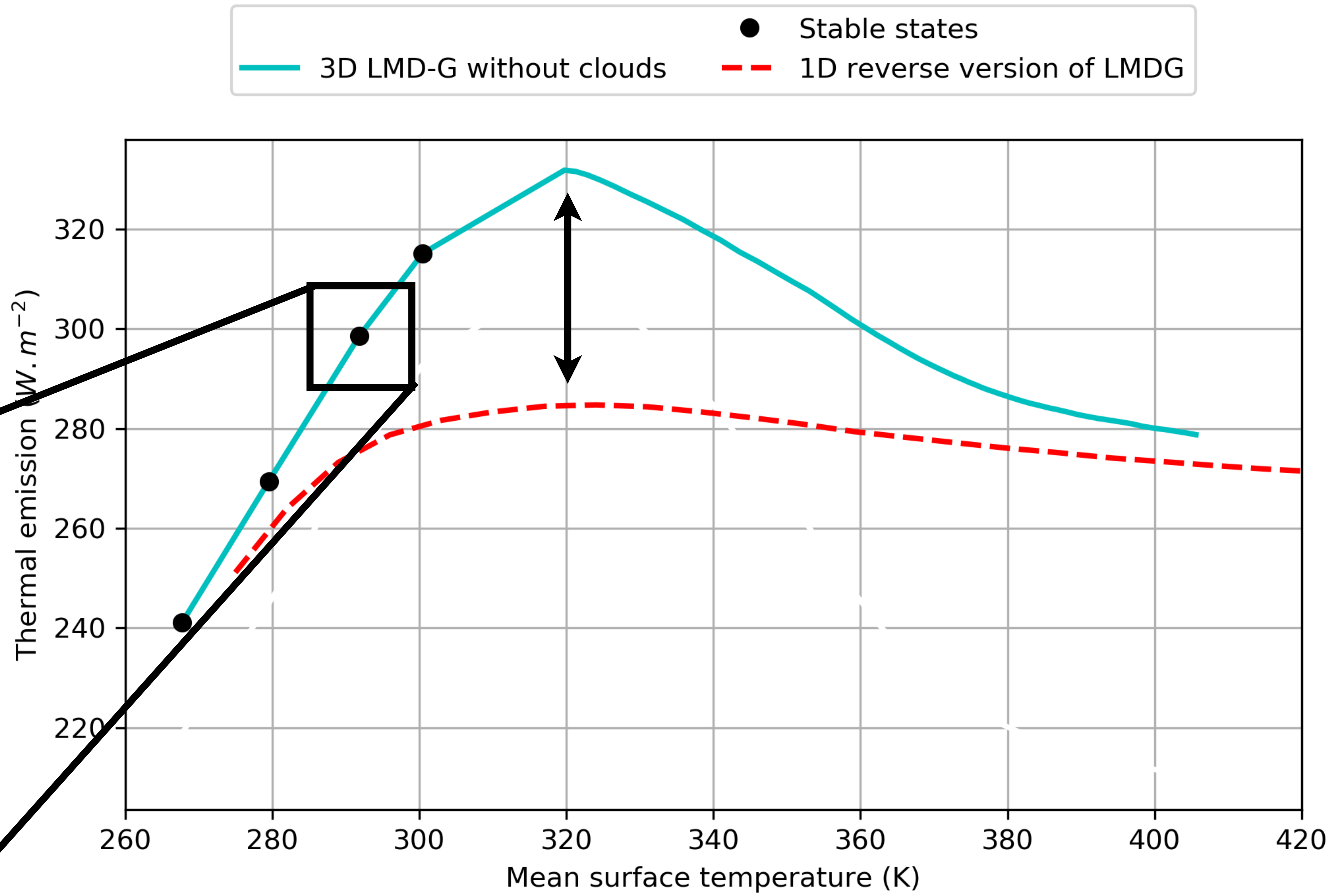

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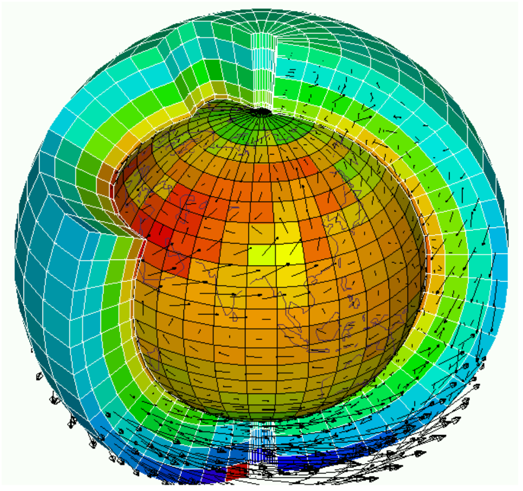
Preliminary results



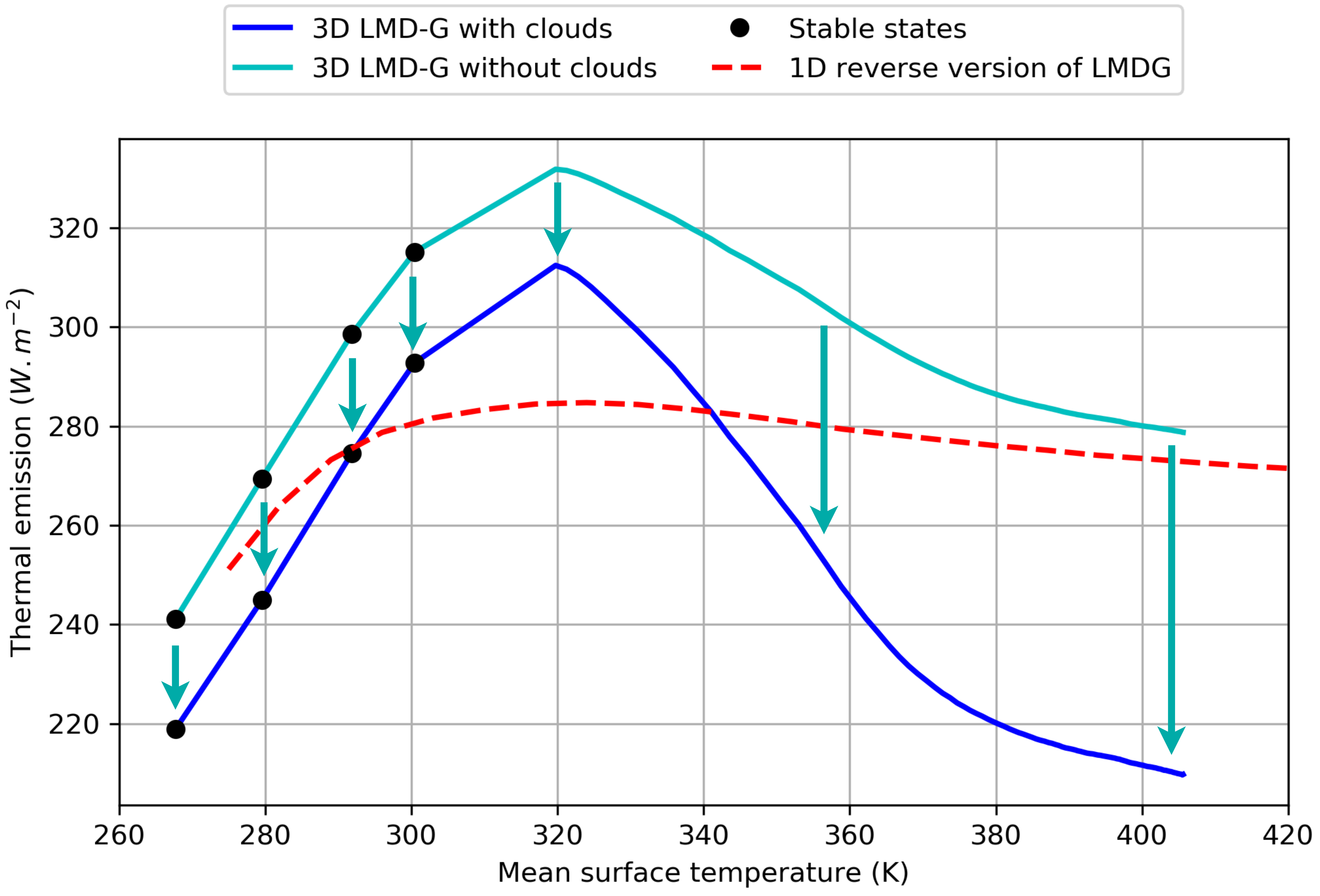
The onset

Effect of the clouds

The maximum thermal emission is stronger in the simulation using the 3D LMD-Generic model

- The **clouds** reduce the thermal emission

Example for P_{N2}=1bar



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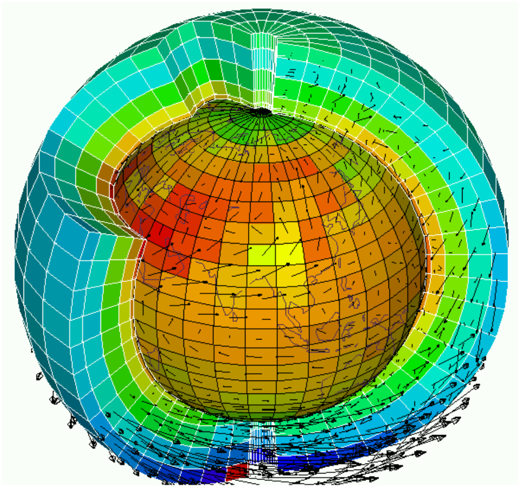


The onset

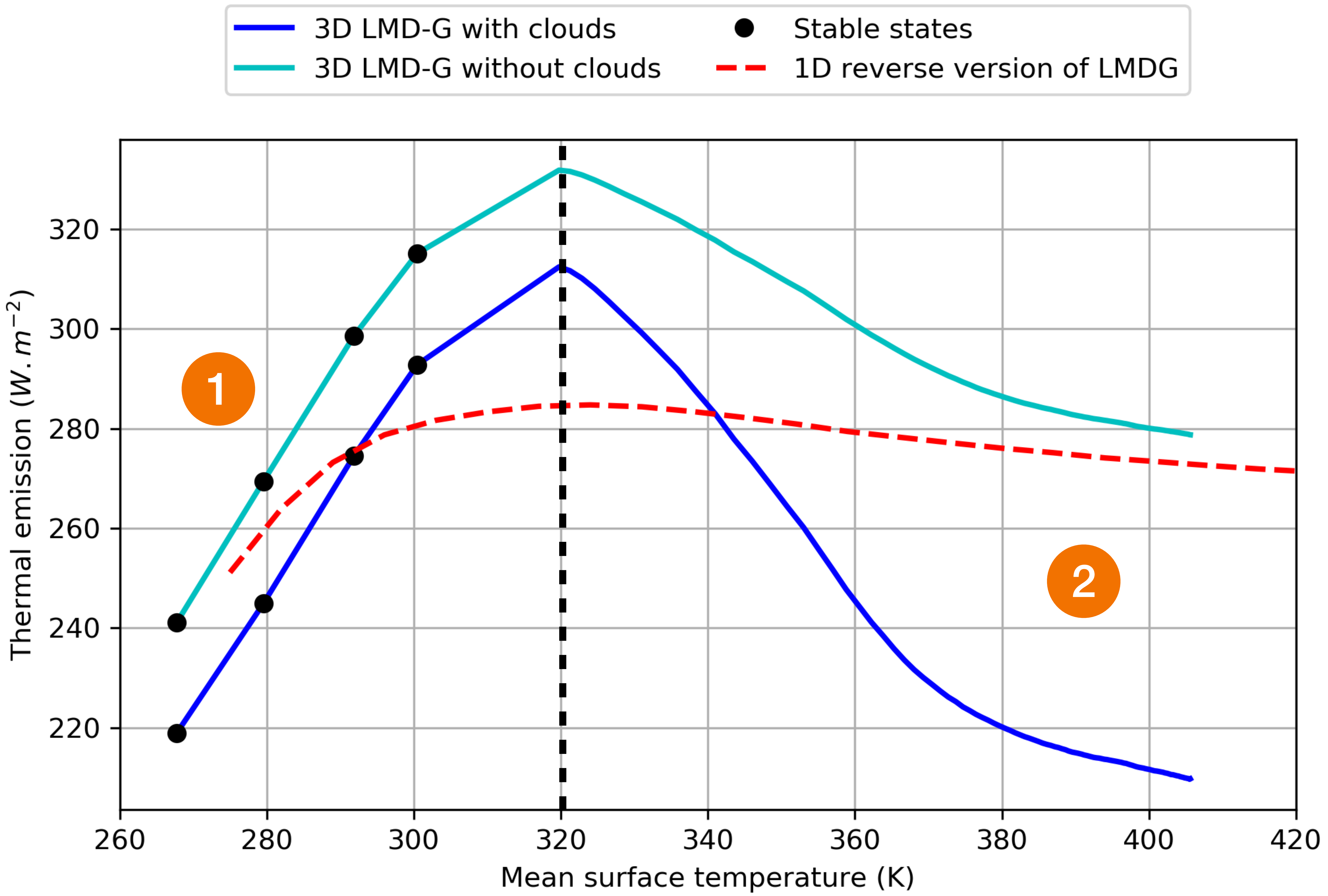
Effect of the clouds

The maximum thermal emission is stronger in the simulation using the 3D LMD-Generic model

- The **clouds** reduce the thermal emission

1. **Constant difference between thermal emission with/without clouds -> constant cloud layer**
2. **Strong evaporation -> more clouds**

Example for P_{N2}=1bar



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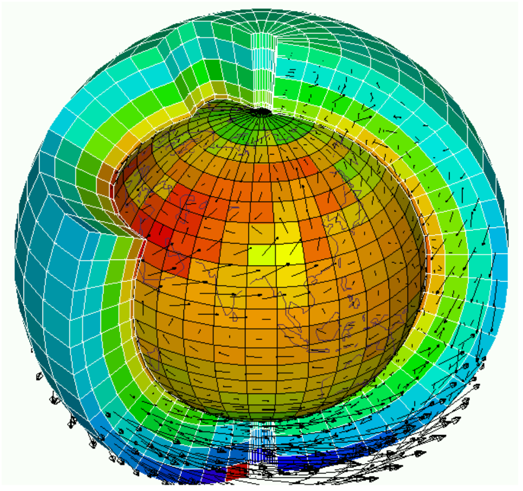
Preliminary results

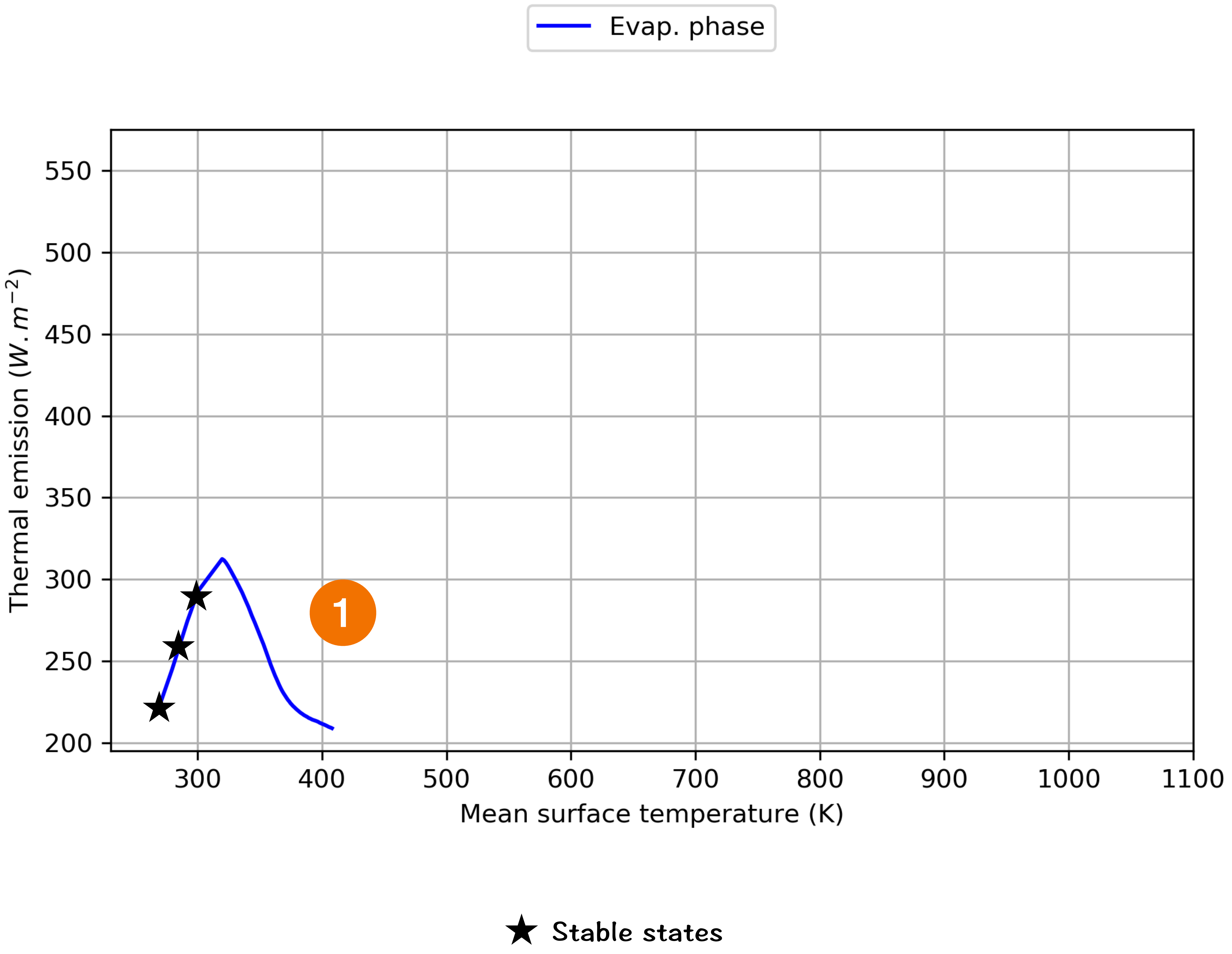


The complete transition

with 3D LMD-Generic

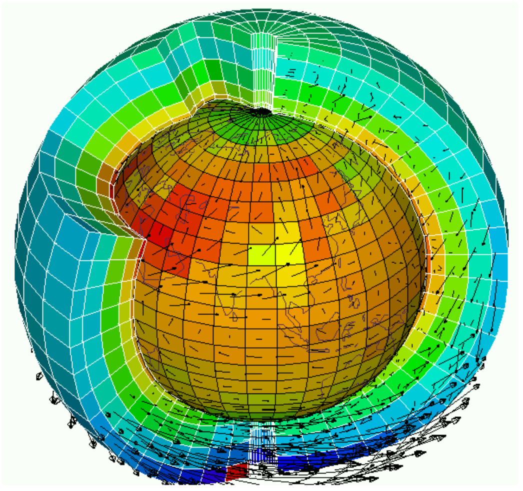
1) The thermal emission **decreases** during the evaporation phase

-> No moist stable states with LMD-Generic



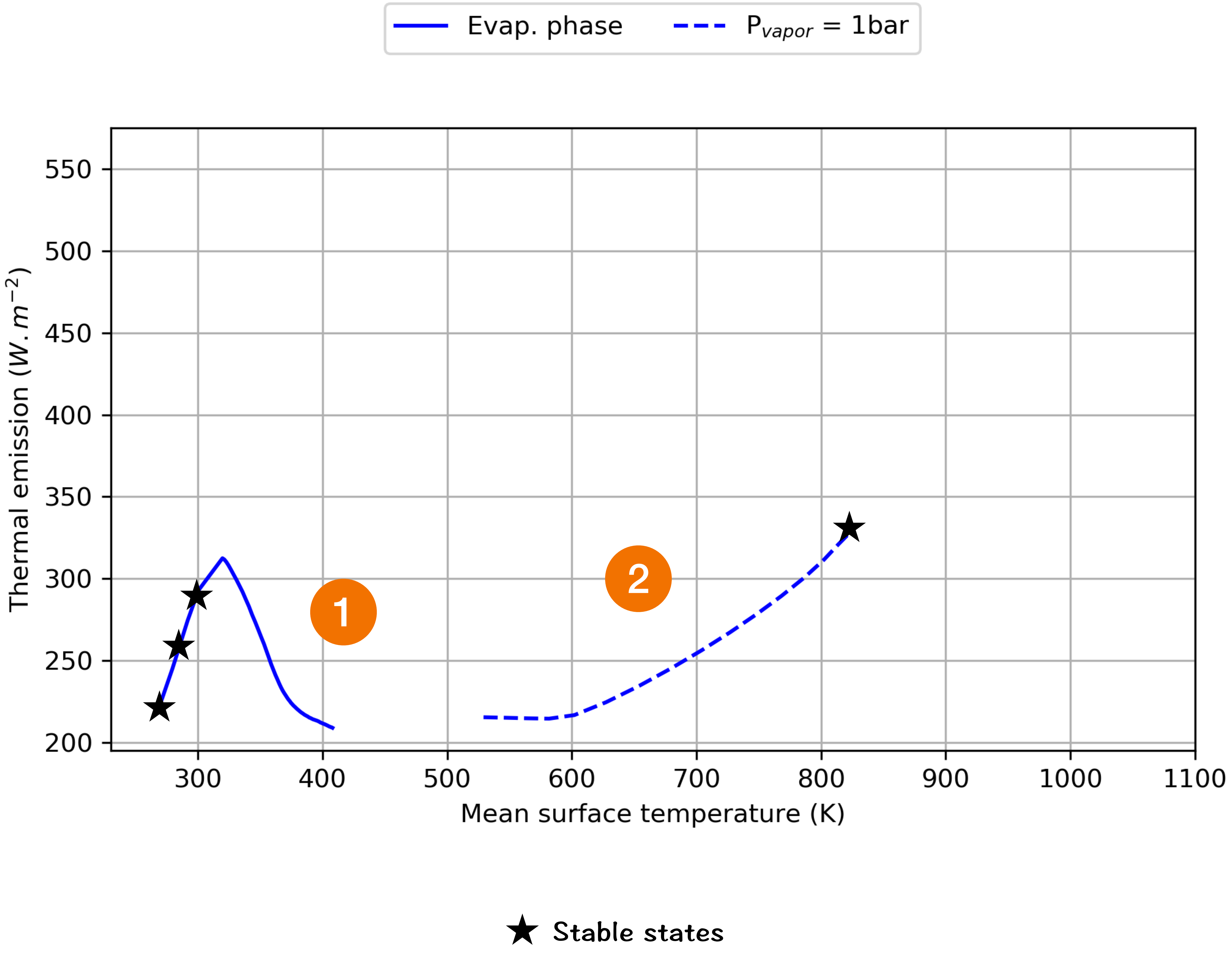
The complete transition
with 3D LMD-Generic

Preliminary results



1) The thermal emission **decreases** during the evaporation phase

2) When there is **no remaining ocean**, the temperature inscreases rapidly and asymptotically



The complete transition

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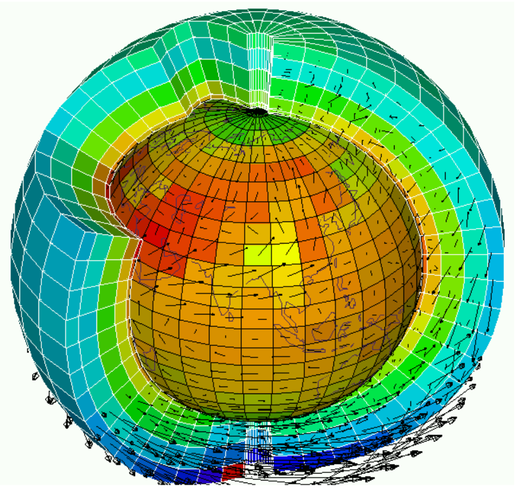
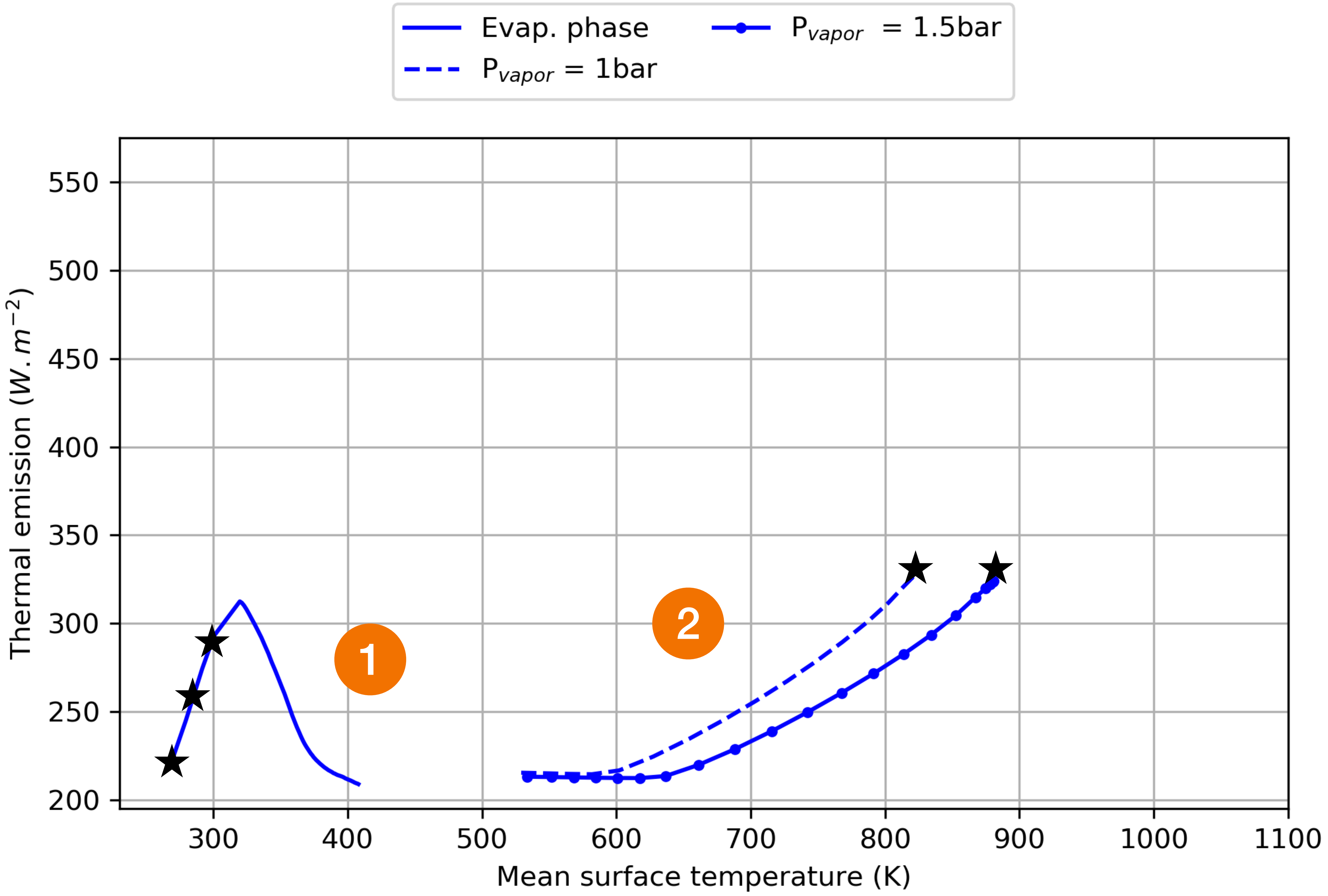
Preliminary results



1) The thermal emission **decreases** during the evaporation phase

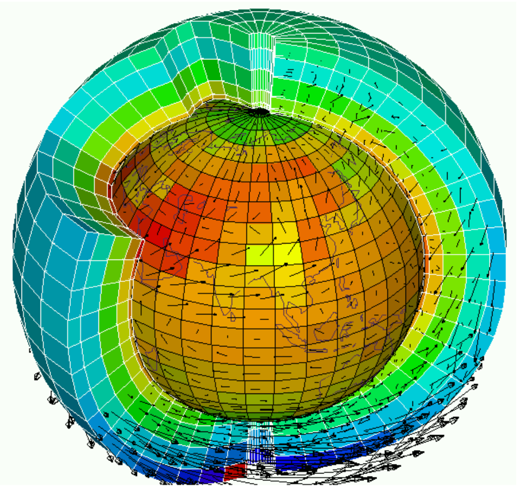
2) When there is **no remaining ocean**, the temperature inscreases rapidly and asymptotically (function of the vapor pressure and the insolation)



★ Stable states

The complete transition
with 3D LMD-Generic

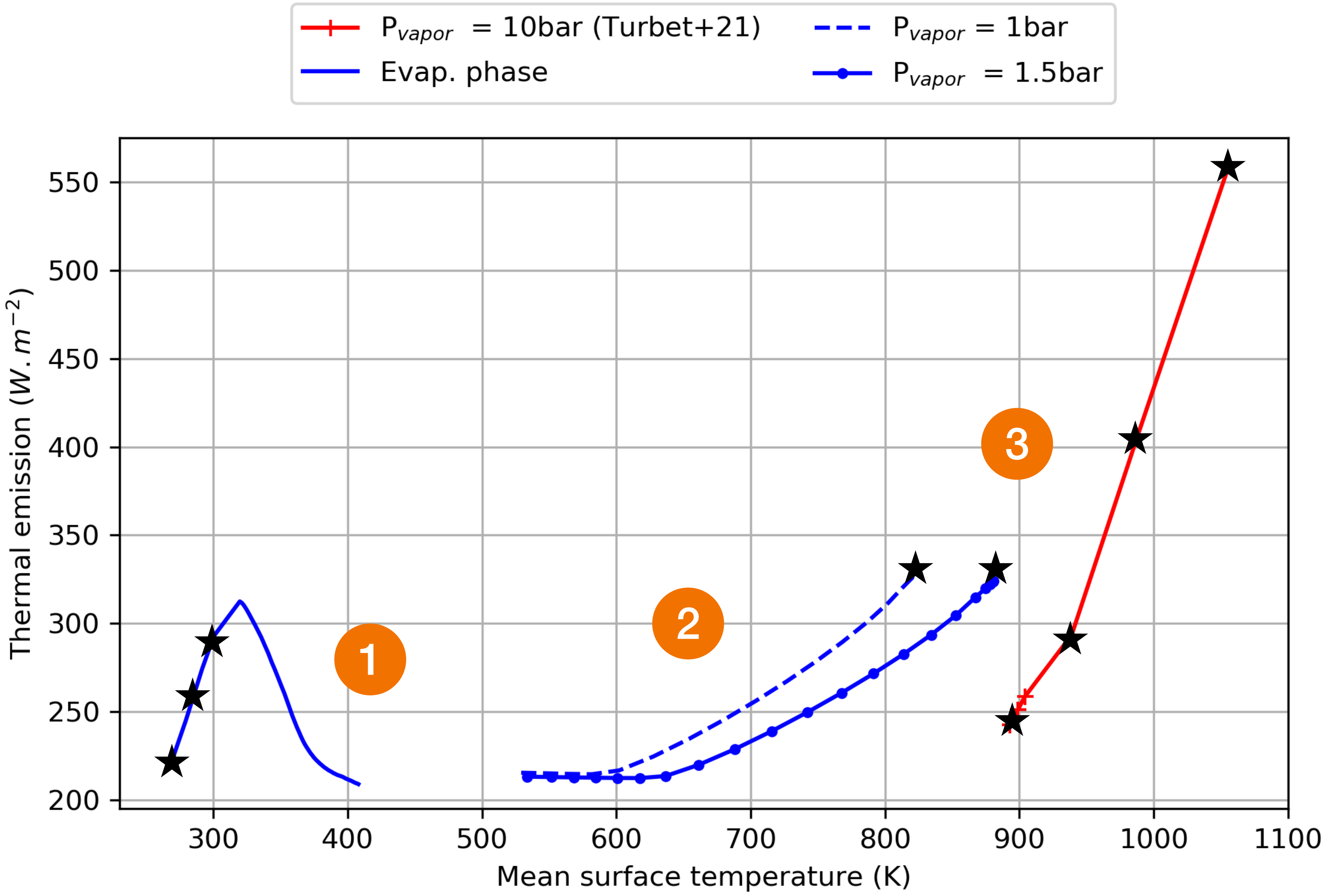
Preliminary results



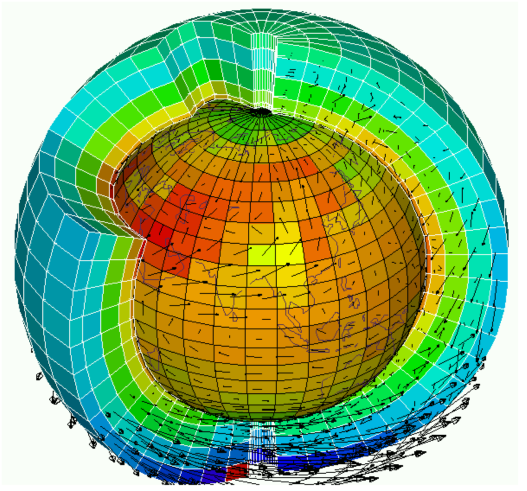
1) The thermal emission **decreases** during the evaporation phase

2) When there is **no remaining ocean**, the temperature inscreases rapidly and asymptotically (function of the vapor pressure and the insolation)

3) The thermal emission increases again to reach a **post runaway state**



★ **Stable states**



The complete transition

with 3D LMD-Generic

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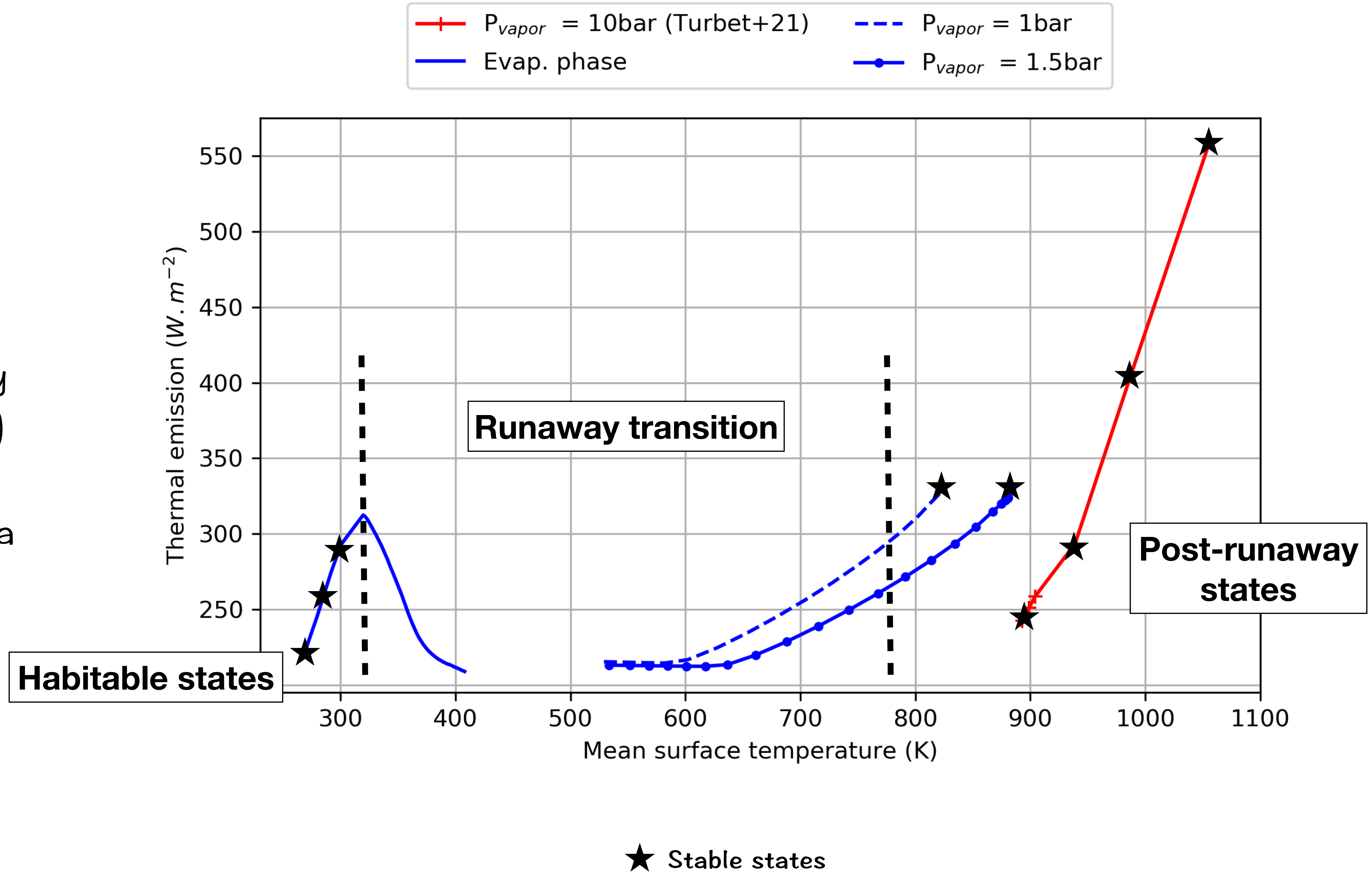

Take away messages

Conclusions of the GCMs simulations:

- The dynamics is the key process for temperate stable states
- The runaway transition is determined by the evolution of the cloud coverage
- After an evaporation phase, when there is no remaing ocean the temperature increase quickly to reach a post runaway state
- Theses post runaway states depend on the vapor pressure