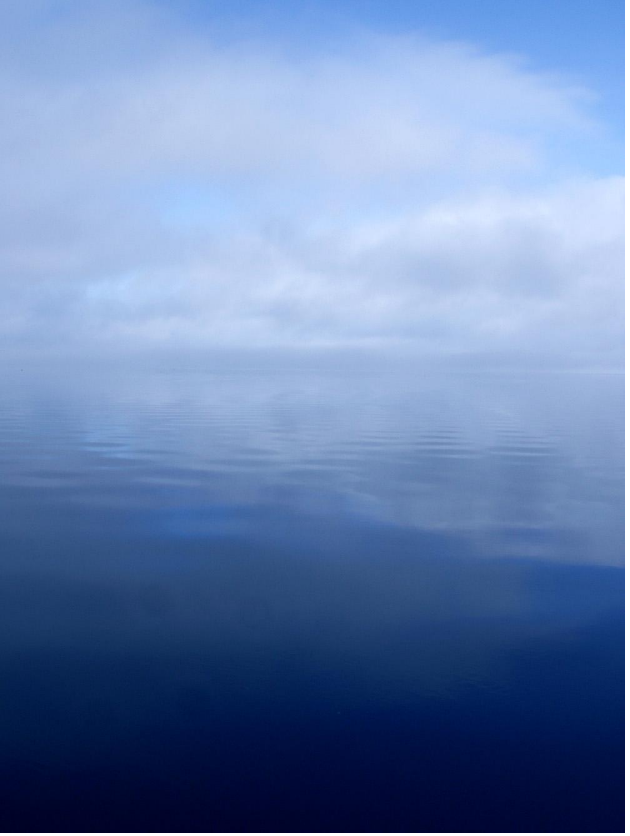
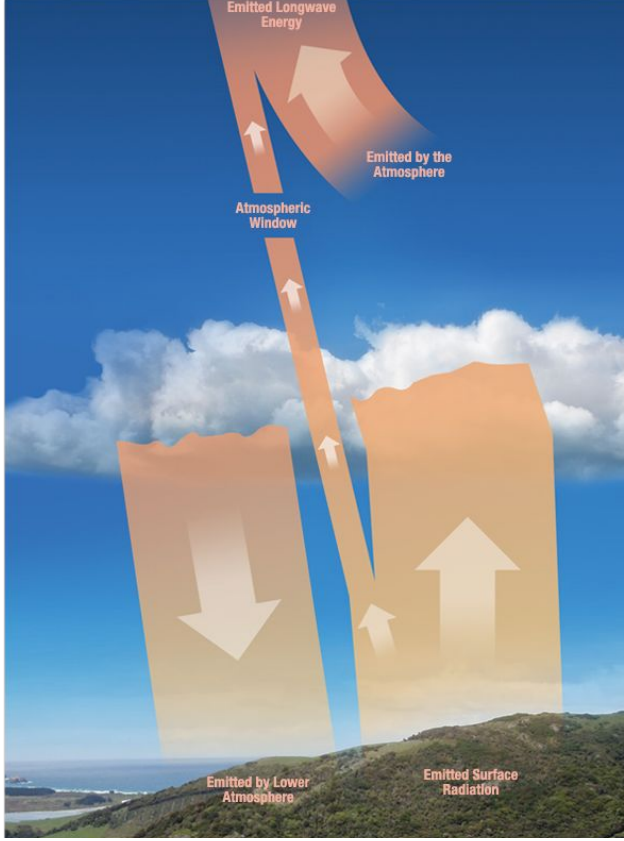




State dependence of the Longwave Clearsky Feedback

Brett McKim, Nadir Jeevanjee, and Geoff Vallis

EGU 2022 Vienna

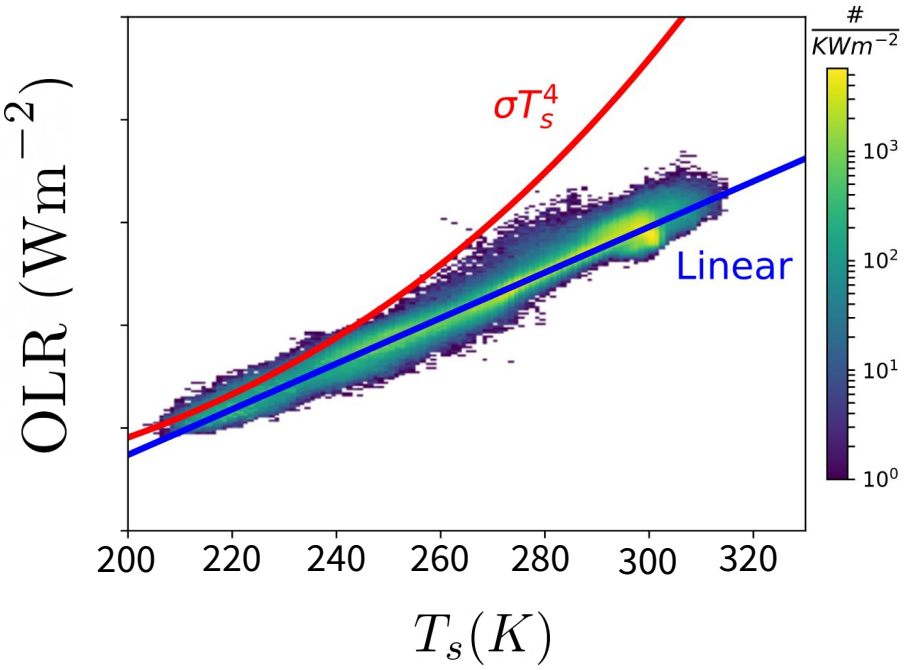
The longwave clearsky feedback is robustly simulated, but is it state dependent?

$$\underbrace{\lambda_{\mathrm{LWCS}}}_{\text{Longwave Clearsky}} = \underbrace{\lambda_{\mathrm{P}}}_{\text{Planck}} + \underbrace{\lambda_{\mathrm{LR}}}_{\text{Lapse Rate}} + \underbrace{\lambda_{\mathrm{RH}}}_{\text{Water Vapor}}$$

$$\lambda_{\mathrm{LWCS}} = \frac{d\mathrm{OLR}}{dT_s} \approx 2\ \mathrm{Wm^{-2}K^{-1}} \pm 10\%$$

Lots of agreement:

Allan et al., 1999
Bony et al., 1995
Budyko, 1969
Cess et al., 1989
Cess et al., 1990
Chung et al., 2010
Dessler et al., 2008
Jeevanjee, 2018
Koll & Cronin, 2018
Raval et al., 1994
Zhang et al., 2020



Koll and Cronin 2018

The longwave clearsky feedback is robustly simulated, but is it state dependent?

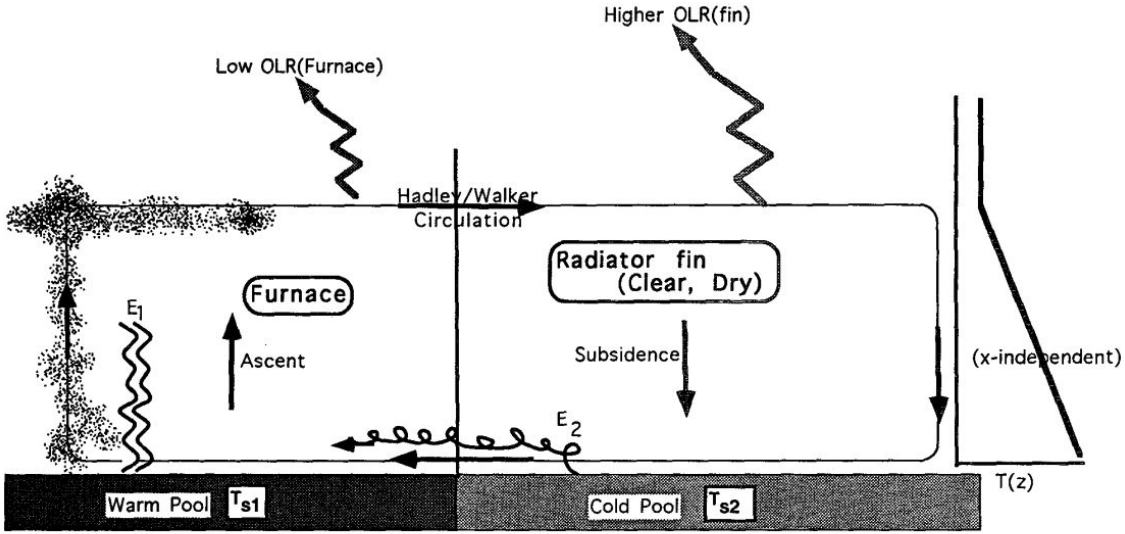
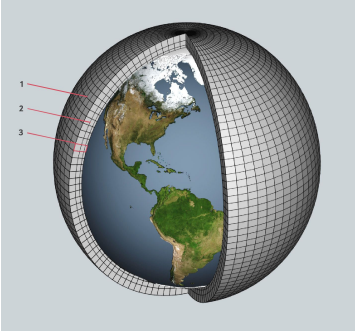


FIG. 7. Schematic representation of the furnace–radiator-fin model of the tropical general circulation.

Dry subtropical regions stabilize the moist deep tropics against the runaway greenhouse

→ **Implies humidity dependent** λ



GCMs have state dependent ECS, largely due to the longwave feedback temperature dependence

→ **Implies temperature dependent** λ

Bloch-Johnson et al 2021, Pierrehumbert 1995

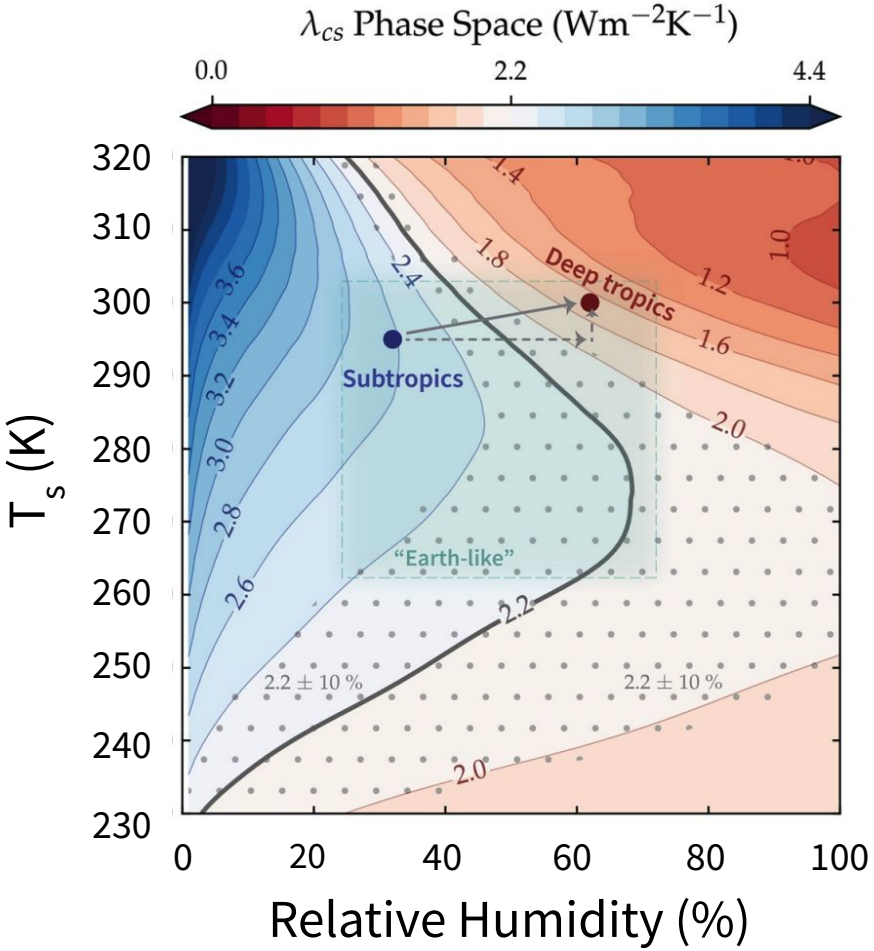
Use idealized column model to probe the state dependence of longwave feedback

Idealizations:

- H_2O-only, longwave radiation only, moist adiabat, isothermal stratosphere, prescribed T_s and RH

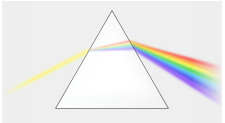
Results

- Phasespace dominated by 2.2 $Wm^{-2}K^{-1}$
- Above 290 K, deviations from 2.2 can occur by changing the relative humidity.
- As the Earth warms, it samples different values of the phase space, changing the global mean feedback



Water vapor physics and the longwave feedback (existing theory)

$$\lambda = \int_0^\infty \Lambda_\nu \mathrm{d}\nu$$

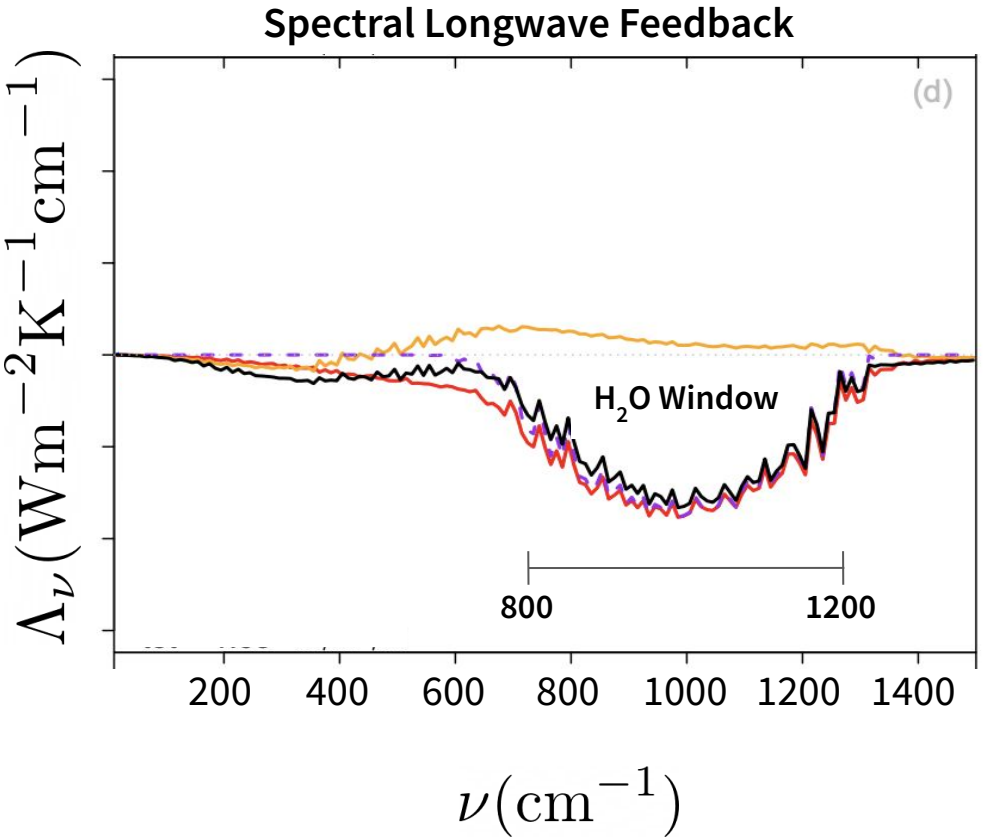


Simpson's "Law": *At fixed RH, and for optically thick wavenumbers dominated by H_2O absorption, OLR is independent of surface temperature*

$$\Lambda_\nu \approx \begin{cases} \pi \mathrm{d}B(\nu, T_s)/\mathrm{d}T_s & \text{inside } H_2O \text{ Window} \\ 0 & \text{outside } H_2O \text{ Window} \end{cases}$$

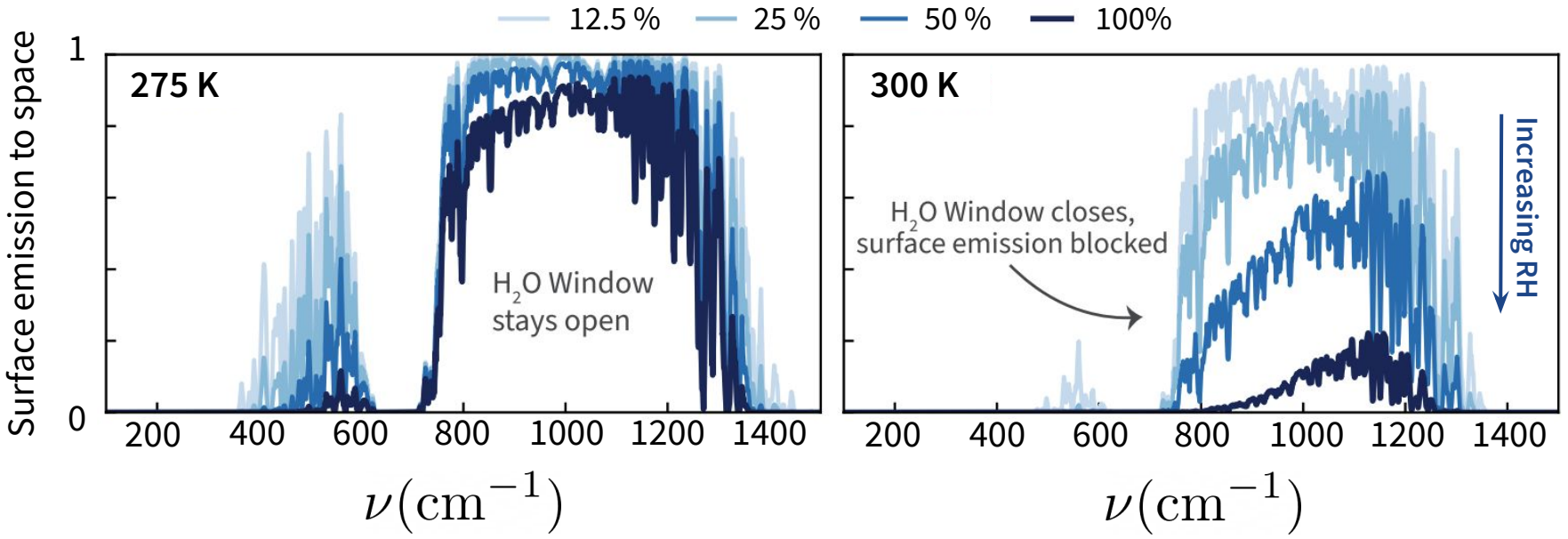
$$\lambda \approx \int_{\nu \in \mathrm{H_2O\ window}} \Lambda_\nu d\nu$$

As T_s increases, Λ_ν increases and H_2O window closes. **Do these opposing influences on λ always cancel?** ---------- **No!**



Koll and Cronin 2018, Jeevanjee 2018, Jeevanjee et al 2021

Closing of the water vapor window drives the state dependence



$$\lambda \approx \int_{\nu \in \mathrm{H_2O\ window}} \Lambda_\nu d\nu$$

At tropical temperatures, RH variations can close the water vapor window and lower λ

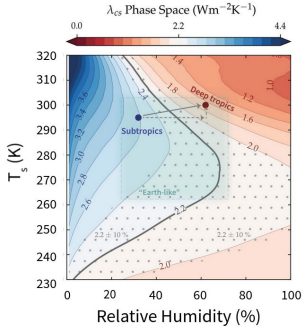
$$\mathrm{Continuum\ Absorption} \sim q^2$$

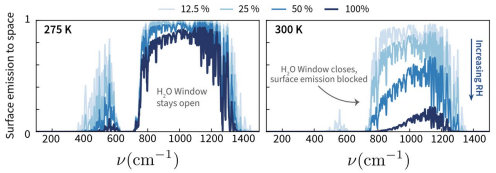
Conclusions

- State-dependence arises when continuum absorption activates at high temperatures, rapidly closing the H_2O window with increased temperature or humidity

- This effect manifests in state dependent climate sensitivity (Bloch-Johnson et al, 2021) and tropical variations in longwave feedback (Pierrehumbert 1995)

- This work might be useful for understanding the clear-sky radiative impact of convective aggregation and circulation-driven changes in humidity





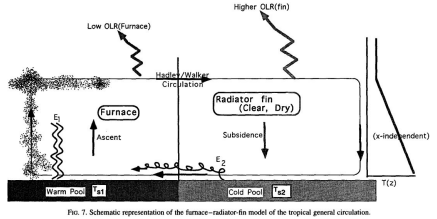
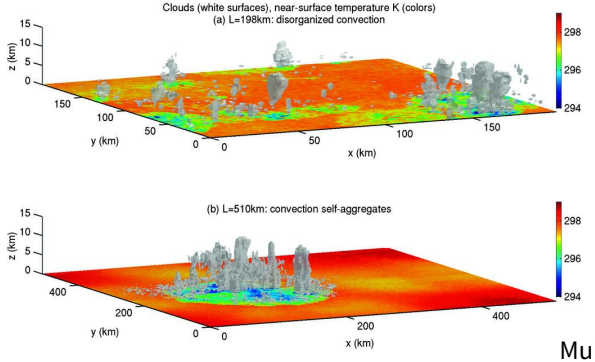


Fig. 7. Schematic representation of the furnace–radiator-fin model of the tropical general circulation.



Muller and Held, 2012

Thanks for watching!

Paper available at brettamckim.com. Incorporates high cloud altitude feedback.

Joint Dependence of Longwave Feedback on Surface Temperature and Relative Humidity

McKim et al, 2021 GRL

For complementary perspectives on the effects of humidity and temperature on LWCS and ECS, see

Dependence of Climate Sensitivity on the Given Distribution of Relative Humidity
Bourdin et al, 2021 GRL

Temperature-Dependence of the Clear-Sky Feedback in Radiative-Convective Equilibrium
Kluft et al, 2021 GRL