The Emergent Linearity of Outgoing Longwave Radiation in a Moist Atmosphere: Implications for the climates of Earth and Extrasolar Planets. Daniel D.B. Koll[1] and Timothy W. Cronin[1], [1]Department of Earth, Atmospheric and Planetary Science, Massachusetts Institute of Technology; dkoll@mit.edu.

Satellite observations and radiative calculations show that Earth's outgoing longwave radiation (OLR) is an essentially linear function of surface temperature over a wide range of temperatures (>60 K; see Figure 1). Although the evidence for a linear relation was first pointed out more than 50 years ago, it is still unclear why this relation is valid.

Linearity implies that Earth's OLR does not follow the non-linearity suggested by the Stefan-Boltzmann law, σT_s^4. Moreover, linearity also has profound consequences for past and future climate change: if OLR is approximately linear, then Earth's longwave climate feedback, $dOLR/dT_s$, is approximately constant, such that radiative forcing has the same impact in warm as in cold climates.

Here we present a simple semi-analytical model that explains Earth's linear OLR as an emergent property of an atmosphere whose greenhouse effect is dominated by a condensible gas. We show that linearity arises from a competition between the surface's increasing thermal emission and the narrowing of spectral window regions with warming, and breaks down at high temperatures once continuum absorption cuts off spectral windows. Our model provides a new way of understanding the longwave contribution to changes in Earth's climate sensitivity. Moreover, our model predicts that atmospheres dominated by exotic condensible greenhouse gases also develop a near-linear OLR, such as hot rocky exoplanets covered with lava oceans and with silicate-oxide vapor atmospheres or cold super-Earths beyond the outer edge of the habitable zone with thick CO_2 oceans and atmospheres. Future space telescopes could thus study these exotic worlds as analogs of our own H_2O-dominated climate.

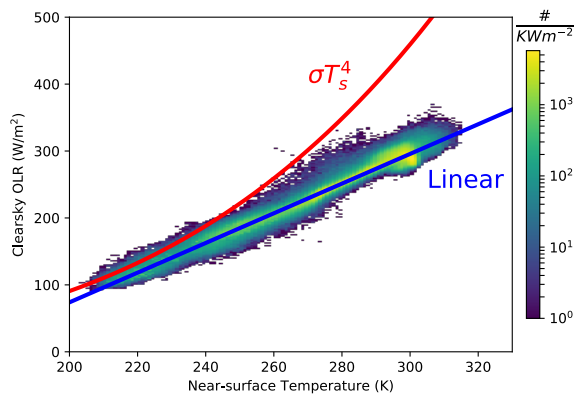

Figure 1: Earth's outgoing longwave radiation (OLR) strongly deviates from the thermal emission of a blackbody, σT_s^4. Instead, the dependence of OLR on surface temperature can be fitted well using a simple linear regression ($r^2 = 0.97$). Shown are monthly-mean clear-sky OLR and near-surface temperatures from satellite and reanalysis datasets.