CLIMATE OF EARTH-LIKE PLANETS WITH AND WITHOUT OCEAN HEAT TRANSPORT ORBITING A RANGE OF M AND K STARS.

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Introduction: The mean surface temperature of a planet is now acknowledged as insufficient to surmise its full potential habitability. Advancing our understanding requires exploration with 3D general circulation models (GCMs), which can take into account how gradients and fluxes across a planet's surface influence the distribution of heat, clouds, and the potential for heterogeneous distribution of liquid water [1]. Here we present 3D GCM simulations of the effects of alternative stellar spectra, instellation, model resolution, and ocean heat transport, on the simulated distribution of heat and moisture of an Earth-like planet (ELP).

Model: We use the ROCKE3D (Resolving Orbital and Climate Keys of Earth and Extraterrestrial Environments with Dynamics), a generalized version of the NASA Goddard Institute for Space Studies (GISS) GCM, which is a well-known community Earth System Model routinely used to simulate the Earth's recent past, current, and future climates [2]. We forced the GCM for the present Earth with different stellar spectral irradiances, with non-interactive atmospheric chemistry ("NINT" configuration of [2]), running the model at 4°x5° with 20 vertical layers for 10 years, and 2°x2.5° with 40 vertical layers until equilibrium, with and without ocean heat transport (OHT).

Stellar spectra and top-of-the-atmosphere instellation used include the Sun-Earth (relative instellation S0X=1), the K2V star HD22049 at S0X=1, the M1V Kepler-186 with S0X=1 and S0X=0.32, and the M3.5V Ad Leo with S0X=1. These were processed to provide the GCM with the top-of-the-atmosphere fraction of total incident energy in broad bands as well as finer spectral irradiance in the UV.

Results: Figure 1 below shows, for fixed SSTs, how the stellar radiation heating rate differs for the modern Sun vs. that of HD22049 and Kepler-186, at an instellation equal to that received by the current Earth. Because of the red-shifted spectral energy distributions of HD22049 and Kepler-186, there is greater absorption by CO_2 and H_2O in the upper atmosphere, reducing the shortwave radiation to the surface. Because of the resulting greater atmospheric stability, precipitation is greatly reduced, despite the same irradiance as the Sun-Earth, with more extreme behavior for Kepler-186 as most red-shifted. Further results compare the time to equilibrium for the different runs, and their differences in surface temperature, precipitation, vertical stellar radiation heating of the atmosphere, and cloud cover.

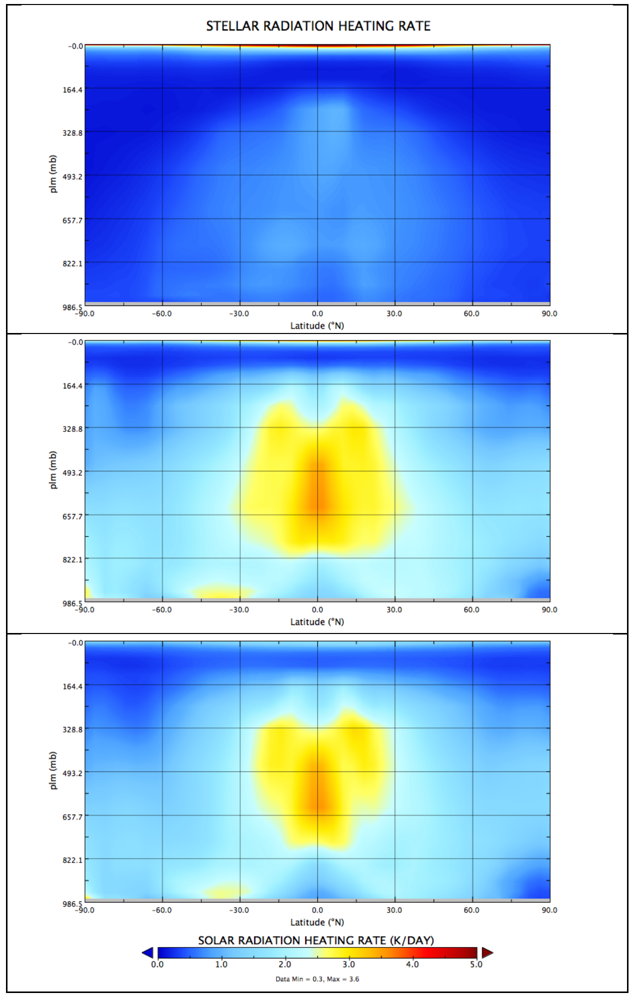

Figure 1. Annual average stellar radiation heating rate of the atmosphere for (top) present Earth, and same instellation but stellar spectra of (middle) HD22049, and (bottom) Kepler-186.

References:

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