DEMARCATING CIRCULATION REGIMES OF SYNCHRONOUSLY ROTATING HABITABLE PLANETS. J. Haqq-Misra[1], E. T. Wolf[2], M. Joshi[3], and R. K. Kopparapu[4], [1]Blue Marble Space Institute of Science (jacob@bmsis.org), [2]University of Colorado Boulder, [3]University of East Anglia, [4]NASA Goddard/University of Maryland.

Summary: M-dwarf stars provide an abundance of environments for potentially hosting habitable planets. The discoveries of Proxima Centauri b around our closest stellar neighbor [1] and the seven planets of the TRAPPIST-1 system [2] indicate that M-dwarfs can harbor terrestrial plants within their liquid water habitable zones [3, 4, 5, 6, 7, 8], which makes them likely targets for upcoming surveys with JWST and TESS. Due to the small size of their host stars, and their short period orbits, habitable planets around M-dwarf stars are the easiest to detect and to characterize their atmospheres.

Speculation that planets in orbit around low-mass stars would be prone to synchronous rotation—so that one side experiences permanent day, while the other experiences permanent night—initially led toward concern that such planets would be prone to freeze out their atmospheres and thus might not be habitable at all [9]. But subsequent investigation with simplified climate models [10] and general circulation models (GCM's) [7, 8, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25] have demonstrated that energy transport from the day to night hemisphere is sufficient to avoid atmospheric collapse across a wide range of atmospheric compositions and rotation rates.

Here we use the Community Atmosphere Model (CAM) to investigate the atmospheric dynamics of terrestrial planets in synchronous rotation around low-mass stars. We show that the temperature contrast between the day and night hemispheres decreases with an increase in incident stellar flux, with little dependence upon stellar spectral type and no dependence upon rotation rate. This trend is opposite that seen on gas giants, where the same forcing shows a *decrease* in the day-night temperature contrast instead.

We define three dynamical regimes in terms of the equatorial Rossby deformation radius and the Rhines length [26]. The slow rotation regime is characterized by the deformation radius exceeding planetary radius, which should occur for planets around stars with effective temperatures of 3700 K to 4500 K. The rapid rotation regime is defined by a deformation radius being less than planetary radius, which occurs for planets orbiting stars with effective temperatures of less than 3000 K. In between these two limits is the Rhines rotation regime with planetary-scale turbulent flow, which occurs for planets around stars with effective temperatures of 3000 K to 3300 K. The dynamical state can be inferred from astronomical observations of orbital period, spectral type of the host star, and the day-night temperature contrast. These dynamical regimes all respond differently to increases in stellar forcing, which also suggests different responses of these atmospheres to the main sequence brightening of their host star.

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