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Changes in atmospheric chemistry on earthlike exoplanets across the habitable zone of main sequence stars

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A coupled radiative-convective photochemical column model has been employed to determine responses in atmospheric biomarkers on a planet having Earth's composition at the inner, mid, and outer Habitable Zone (HZ) for a solar, F2V and K2V star. We defined the HZ conservatively to be suitable for humans i.e. 0 degrees C $<$ Tsurface $<$ 30 degrees C. This resulted in the model calculating a narrow HZ width of (0.95-1.09) Astronomical Units (AU) for the solar-type star, (1.59-1.80) AU for the F2V star and (0.51-0.59) AU for the K2V star. Although the HZ was narrow, the biomarkers H2O, CH4 and CH3Cl varied by large amounts i.e. by factors 11, 22 and 19 respectively in the column on moving outwards across the solar HZ, for example. We found that H2O decreased on moving outwards across the HZ due to enhanced condensation in the troposphere. CH4 and CH3Cl increased associated with a slowing in H2O+O1D–$>$2OH, hence less OH, an important sink for these two compounds. Ozone changes were smaller, around a factor of two increase across the HZ, partly due to a decrease in its photolytic sink. We also considered changes in species which impact ozone - the so-called family species (and their reservoirs) which can catalytically destroy ozone. HCl, for example is a chlorine reservoir (storage) molecule, which increased by a factor 5-10 on moving outwards over the solar HZ. For the F2V and K2V stars, similar sources and sinks dominated the chemical biomarker budget as for the

solar case and columns trends were comparable across the HZ. Ratios of biomarkers are more straightforward to detect than absolute levels. Our results imply that, even for a conservatively-defined HZ, ratios such as (O3/H2O) and (CH4/H2O) can change by sometimes large amounts and still be consistent with habitability.