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Teaching Astronomical Concepts Relevant to Earth and Climate Sciences with *AstroGeoVis 1.0* : Leveraging Scientific Computing and Dynamic Visualizations

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Solar irradiance is one of the defining factors determining Earth's climate and habitability. Thus, comprehension of Earth's orbital parameters, and the resulting apparent motions of the Sun on the celestial sphere and spatio-temporal patterns of insolation, is an important part of climate literacy. The Earth orbit v2.1 model (Kostadinov and Gilb, 2014, GMD) focused on 3D Earth orbit, Milankovitch cycles and insolation visualization and analysis with research and pedagogical applications. Here I introduce *AstroGeoVis v1.0* – software that performs astronomical visualizations relevant to Earth and climate science, with a focus on the apparent motions of the Sun on the celestial sphere and related concepts, with primarily pedagogical applications in mind. Specifically, *AstroGeoVis v1.0* computes solar equatorial and local horizontal coordinates (using the Meeus (1998) algorithms) and uses first principles to compute and visualize various phenomena such as the terminator, daily path of the Sun on the celestial sphere, shadow geometry, the equation of time and the analemma, seasonality and daylength. Instantaneous irradiance on a randomly oriented solar panel is computed and used to determine annual energy production and optimize panel orientation, demonstrating numerical integration and optimization. This component of *AstroGeoVis v1.0* is particularly relevant in the context of the increasing importance of solar renewable energy and sustainable practices such as passive building design, requiring that an increasing number and variety of professionals be familiar with Sun-Earth geometry and related concepts.

AstroGeoVis v1.0 was written in MATLAB© and is open source. I provide multiple examples and ideas for classroom use, including a complete exercise in which students track solar declination throughout the semester via shadow length and azimuth measurements. The software has multiple pedagogical advantages, e.g. figures are dynamic and can be re-created by the instructor, for example for a specific latitude, some are 3D and have pan/tilt/zoom capability. The scientific code itself can be inspected, modified and improved by instructors and students as needed, i.e. it is intended that the code as well as the visualizations will be used in instructional settings. This makes *AstroGeoVis v1.0* applicable in pedagogical settings at many levels, across many disciplines, e.g. physical geography, oceanography, meteorology, climatology, Earth system science, physics, astronomy, mathematics and computer science. Earth sciences, like many other disciplines, have increasingly become highly quantitative and computational in nature, dealing

with large numerical data sets (e.g. climate model development and analysis). *AstroGeoVis v1.0* is intended to help students master not only astronomical concepts relevant to Earth and climate sciences, but also acquire scientific computing and data analysis skills, which are becoming increasingly indispensable for a wide variety of careers.