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Heliophysics Concept Maps for Education and Public Outreach

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Abstract. The NASA Science Mission Directorate Heliophysics Science Education and Public Outreach Forum team has created a set of Heliophysics Concept Maps. The concepts are based on content related to the three major questions in the NASA Heliophysics Science Roadmap: What causes the Sun to vary? How do the Earth and the heliosphere respond? What are the impacts on humanity? These maps tie into the AAAS Project 2061 Benchmarks for Scientific Literacy, a set of K–12 learning goals that are widely used by education professionals for curriculum development and program planning. The purpose of this effort was to identify key concepts related to heliophysics and map their progression to show how students' understanding of heliophysics might develop from kindergarten through higher education. This effort creates more comprehensive maps specific to heliophysics that provide content at a deeper level than what is in the existing Benchmarks. It also extends the concept maps to higher education, an audience not included in the Benchmarks.

1. The Need

In recent years, it has become clear that there is a distinct need for a resource to outline heliophysics concepts that are, and more importantly, are *not* included in documents such as the AAAS Benchmarks or the science education standards, including solar variability, plasma and magnetic process on the Sun, solar flares, coronal mass ejections, and the influence of these processes on Earth and other planets. The most relevant materials available that include some of these concepts are the concept maps developed for the GEMS Space Science Sequence for grades 3–5 and grades 6–8.

The concept maps outline three sets of concepts to form a Mini-Atlas of Heliophysics Literacy in order to:

- provide a way for heliophysics EPO professionals to understand how their formal education (including higher education) and informal education products tie to general overarching heliophysics concepts, and

- provide a way for educators or curriculum designers to tie heliophysics concepts together with related science concepts.

Iterations of the maps may also be included in NASA Wavelength[1] at some point in the future.

2. What Is Heliophysics?

Heliophysics research and exploration focuses on studying the Sun, the heliosphere, and planetary environments as elements of a single, interconnected system that contains dynamic space weather and evolves in response to solar, planetary, and interstellar conditions. Such an understanding represents not just a grand intellectual accomplishment for our times, it also provides knowledge and predictive capabilities essential to protecting our current technological infrastructure and supports the future utilization and exploration of space.

Earth moves through the heliosphere, the exotic outer atmosphere of our star. The space beyond Earth's protective atmospheric cocoon is highly variable and far from benign. The Sun, our solar system, and the region of the galaxy just outside the solar system present us with a complex, interacting set of physical processes. It is the one part of the cosmos accessible to *in situ* scientific investigation, our only hands-on astrophysical laboratory.

We do not live in isolation; we are intimately coupled with the Sun and the space environment through Earth's climate system and our technological systems. The habitability of planets and solar system bodies we plan to explore, and ultimately the fate of Earth itself, depend on the Sun. Variability in this environment affects the daily activities that constitute the underpinning of modern society, including communication, navigation, and weather monitoring and prediction. Because the space environment matters to humans and their technological systems both on Earth and in space, it is essential as a space-faring nation that we develop an understanding of these space plasma processes.

3. Conceptual Background

The concepts contained in the maps are based on content related to the three major questions in the NASA Heliophysics Science Roadmap: *What causes the Sun to vary? How do the Earth and the heliosphere respond? What are the impacts on humanity?* The AAAS Atlas of Science Literacy strand maps have been used as templates for several of the Heliophysics Concept Maps; the Atlas is derived from the AAAS Project 2061 Benchmarks for Scientific Literacy, a set of K–12 learning goals that are widely used by education professionals for curriculum development and program planning. The purpose of this effort was to identify key concepts related to heliophysics and map their progression to show how students' understanding of heliophysics might develop from kindergarten through higher education. This effort creates more comprehensive maps specific to heliophysics that provide content at a deeper level than what is included in the existing Benchmarks; this effort also extends the concept maps to higher education, an audience not included in the Benchmarks. One main difference, however, between the AAAS Atlas of Science Literacy strand maps and the Heliophysics Mini-Atlas is

[1] http://www.nasawavelength.org

that the Benchmarks and strand maps only cover concepts for grades K–12. The Mini-Atlas of Heliophysics Literacy includes K–12 concepts and those that extend to higher education.

These concept maps have been designed and assembled through the combined efforts of a number of heliophysics EPO community members and Heliophysics Forum team members, and input was gathered from EPO community members at various stages of the development process. The development team feels that these maps can serve the community well for the development of future heliophysics educational materials.

The higher education concepts are not meant to be an exhaustive list to cover every possible topic related to heliophysics that an astronomy or astrophysics major might encounter in the upper levels of coursework. Rather, these concepts are those that would more likely be taught in Astro 101 or similar courses. The concepts listed in the grades 9–12 levels can also be combined with the higher education concepts, as students in higher education may not have had exposure to the grades 9–12 concepts in high school science classes.

4. The Concept Lists and Maps

The concept maps are available to the NASA Science Mission Directorate Heliophysics Education and Public Outreach community on the community workspace. Please note that at the time of submission of this paper the concepts and maps were not publicly available.

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