# High School Four-Course Model: Earth and Space Sciences

## Introduction to the Earth and Space Sciences Course

According to the Next Generation Science Standards:

> Students in high school develop understanding of a wide range of topics in Earth and Space Science (ESS) that build upon science concepts from middle school through more advanced content, practice, and crosscutting themes. There are five ESS standard topics in high school: Space Systems, History of Earth, Earth's Systems, Weather and Climate, and Human Sustainability. The content of the performance expectations are based on current community-based geoscience literacy efforts such as the Earth Science Literacy Principles (Wysession et al., 2012), and is presented with a greater emphasis on an Earth Systems Science approach. There are strong connections to mathematical practices of analyzing and interpreting data. The performance expectations strongly reflect the many societally relevant aspects of ESS (resources, hazards, environmental impacts) with an emphasis on using engineering and technology concepts to design solutions to challenges facing human society. While the performance expectations shown in high school ESS couple particular practices with specific disciplinary core ideas, instructional decisions should include use of many practices that lead to the performance expectations. (NGSS Lead States 2013c)

By the time students enter high school, they are able to develop a sophisticated understanding of processes that shape the world around them. Earth science is a central part of the CA NGSS, and this document lays out a rigorous high school laboratory course that addresses the new standards.

The emphasis within the CA NGSS is on the processes that shape our Earth. These processes are best understood when thinking about the Earth as a "system of systems." A **system [CCC-4]** includes component parts, interactions between those parts, and exchanges of energy and matter to the world outside the system. Each of the following Earth systems is shaped by its internal workings and its interactions with the other systems:

- Atmosphere: gases around the Earth (i.e., our air)
- Hydrosphere: all the water (sometimes ice is considered separately as the cryosphere)
- Geosphere: inorganic rocks and minerals
- Biosphere: all life

- Anthrosphere: humanity and all of its creations (This sphere is not specifically mentioned in the *NRC Framework* because it is primarily part of the biosphere. Separating this sphere out emphasizes the significant influences humans have on the rest of Earth's systems and is consistent with the Environmental Principles and Concepts [EP&Cs] that are part of the CA NGSS.)

The CA NGSS has titled this discipline Earth and space sciences (ESS) to emphasize that while Earth exists as a singular planet, its systems are strongly influenced by interactions with the broader universe.

While the DCIs explore a range of interactions, the NGSS authors state that interactions between the anthrosphere and the other **systems [CCC-4]** should always be a large part of the discussion: "The performance expectations strongly reflect the many societally relevant aspects of ESS (resources, hazards, environmental impacts) with an emphasis on using engineering and technology concepts to design solutions to challenges facing human society" (NGSS Lead States 2013c).

The CA NGSS do not specify which phenomena to explore or the order to address topics because phenomena need to be relevant to the students that live in each community and should flow in an authentic manner. This chapter illustrates one possible set of phenomena that will help students achieve the CA NGSS performance expectations. Many of the phenomena selected illustrate California's EP&Cs, which are an essential part of the CA NGSS (see chapter 1 of this framework). However, the phenomena chosen for this statewide document will not be ideal for every classroom in a state as large and diverse as California. When bringing the CA NGSS to their classroom, Earth science teachers have great opportunities to make the subject matter regionally relevant. Coastal communities may wish to focus on different spheres of interaction than farming communities in the Central Valley. Despite these regional differences, a large fraction of California's students live in densely urban communities where ties to the natural environment are less apparent. When describing possible directions for meeting the performance expectations, this chapter identifies options most relevant for urban youth and also includes an entire segment to explore urban geoscience issues.

This example course is divided into instructional segments centered on questions about observations of a specific phenomenon. Different phenomena require different amounts of investigation to explore and understand, so each instructional segment should take a different fraction of the school year. As students achieve the performance expectations within the instructional segment, they uncover DCIs from Earth and space sciences and engineering. Students engage in multiple practices in each instructional segment, not only those explicitly indicated in the performance expectations. Students also focus on one or two CCCs as tools to make sense of their observations and investigations; the CCCs are recurring themes in all disciplines of science and engineering and help tie these seemingly disparate fields together.

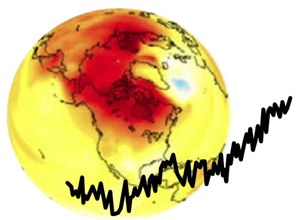
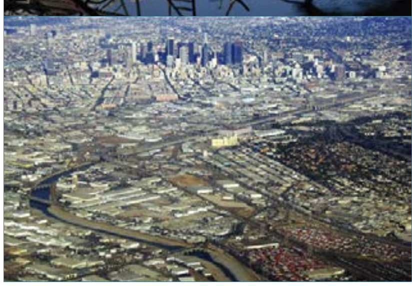
This chapter clarifies the general level of understanding required to meet each performance expectation, but the exact depth of understanding expected of students depends on this course's place in the overall high school sequence. Teachers could modify the content and complexity so that the course serves as a basic freshman introduction to science, serves as a senior capstone that integrates and applies science learning from all previous science courses, or aligns with the expectations of advanced placement or international baccalaureate curriculum.

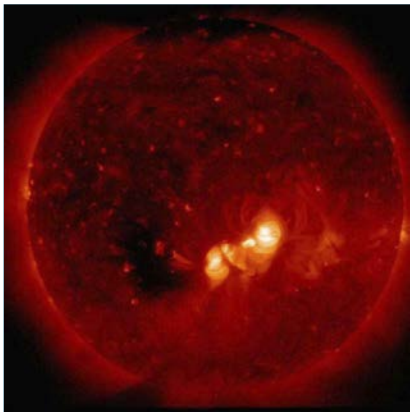
## Example Course Mapping for an Earth and Space Sciences Course

The CA NGSS DCIs for ESS are intentionally organized by scale and sequence: from the beginning of the universe toward the present and from the inside of the Earth to the outside. While this sequence is an excellent framework for organizing the present-day state of knowledge about ESS, it does not fully reflect the process of scientific discovery nor is that sequence consistent with the stated emphasis to "design solutions to challenges facing human society" (NGSS Lead States 2013c). While topics such as the origin of our universe inspire great curiosity, their solutions have less direct and tangible impact on human lives. A large focus of this course is on energy and climate issues (table 8.8; figure 8.44). The course begins with a tangible and relevant example of a phenomenon that illustrates Earth's interacting systems, the formation and extraction of fossil fuels such as oil and gas. That instructional segment then motivates the study of climate change, IS2, because it illustrates a direct **cause and effect [CCC-2]** relationship between human activities and the natural climate system. Subsequent instructional segments explore other interactions within Earth's systems and then revisit the issue of how climate change could impact those particular Earth systems.

Despite this overall emphasis on the interaction between Earth systems and humans today, the course ends with two instructional segments that discuss the Earth's place in the universe. These instructional segments address fundamental questions related to our origin and emphasize that the human desire to understand is also an essential part of scientific practice.

**Table 8.8. Overview of Instructional Segments for High School Earth and Space Sciences**

| | |
|---|---|
|  | **1 Oil and Gas**<br>Oil and gas are resources that allow us to harness energy from ancient life but also cause us to unleash ancient carbon into the atmosphere. |
|  | **2 Climate**<br>Data reveal that carbon in our atmosphere has a big impact on global temperatures and climate. Humans, in turn, have a big impact on carbon in our atmosphere. |
|  | **3 Mountains, Valleys, and Coasts**<br>Water shapes and sculpts our landscapes. The process is sometimes thought of as slow and steady but often occurs as catastrophic events when driving forces exceed resisting forces. |
|  | **4 Water and Farming**<br>California depends on its precious water resources to sustain its people and its farms. |
|  | **5 Causes and Effects of Earthquakes**<br>Earthquakes and motion at the surface give clues to what goes on deep inside the Earth. |
|  | **6 Urban Geo-science**<br>The majority of California residents live in urban areas that are shaped by the natural environment. Our urban expansion in these areas requires that we also think about how human activity in turn affects the natural environment. |



**7 Star Stuff**

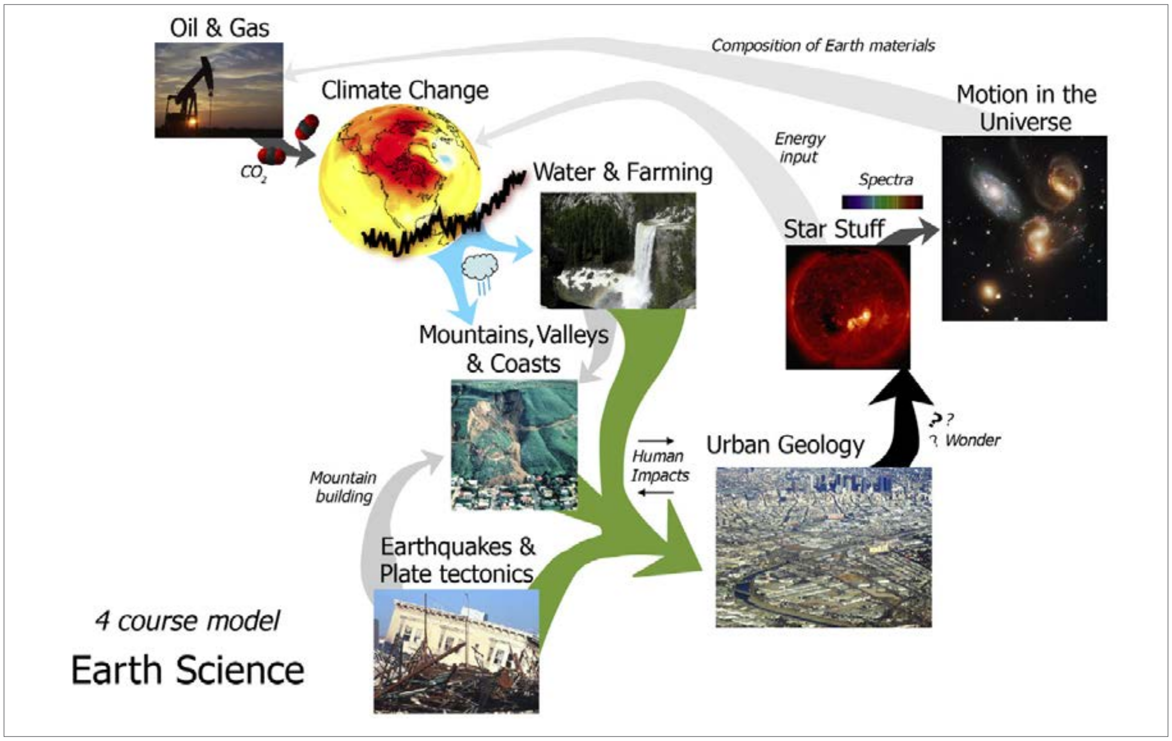
Everything on Earth is made of "star-stuff." Earth depends on its closest star, the Sun, for almost all its energy. The light from all stars provides clues about what they are and how they shine.

**8 Motion in the Universe**

The structure of objects in our universe and the motions of all bodies within it are driven by the competition between the explosive force of the Big Bang and the attractive force of gravity.

*Sources*: Kounce 2008; adapted from Geophysical Fluid Dynamics Laboratory 2007; United States Geological Survey/Photo by R.L Schuster 2004; Seigmund 2006; United States Geological Survey/Photo by Charles E. Meyer 1999; Reiring 2009; National Astronomical Observatory of Japan, Institute of Space and Astronautical Science/Japan Aerospace Exploration Agency 2006; NASA, ESA, and the Hubble SM4 ERO Team/Space Telescope Science Institute 2009

**Figure 8.44. Conceptual Flow of Instructional Segments in High School Earth and Space Sciences Course**




*Sources*: Kounce 2008; adapted from Geophysical Fluid Dynamics Laboratory 2007; Seigmund 2006; United States Geological Survey/Photo by R.L Schuster 2004; United States Geological Survey/Photo by Charles E. Meyer 1999; Reiring 2009; National Astronomical Observatory of Japan, Institute of Space and Astronautical Science/Japan Aerospace Exploration Agency 2006; NASA, ESA, and the Hubble SM4 ERO Team/Space Telescope Science Institute 2009
Long description of Figure 8.44.