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Hold that thought.

We'll come back to it soon.

Profound Ideas About the Earth System

Don Duggan-Haas
dugganhaas@museumoftheearth.org
The Paleontological Research Institution
& its Museum of the Earth

NSTA 2010, Philadelphia, PA

Presentation Overview

Presentation Overview

- Literacy Initiatives Background

Presentation Overview

- Literacy Initiatives Background
- Implications of the current situation

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  - A word about the new national standards

First...

A word from our sponsors.

PALEONTOLOGICAL
RESEARCH INSTITUTION

NSF

The ReaL Earth Inquiry Project

ReaL Earth System Science is a project of the Paleontological Research Institution (PRI) that is funded by NSF (DRK-12 0733303). The project helps teachers teach **Re**gional **a**nd **L**ocal Earth system science using an inquiry-based approach, as a way to understand the global environment.

This is undertaken through several components:

- A series of 7 regional Teacher Friendly Guides (TFGs) to the geoscience of the United States. teacherfriendlyguide.org
- Teacher professional development programs
- The creation of Virtual Fieldwork Experiences (VFEs) virtualfieldwork.org

What do you think?

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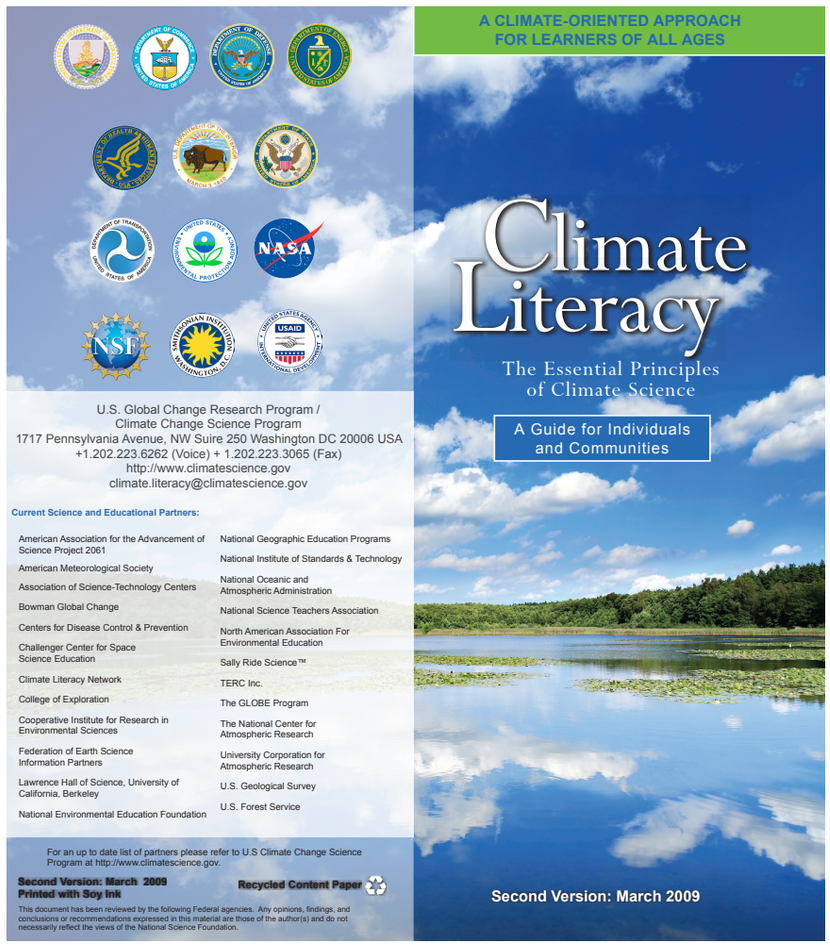
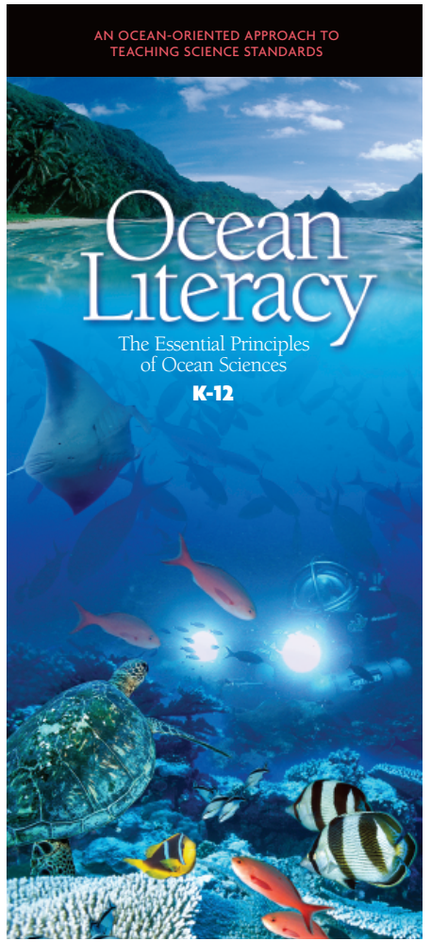
- **What would your students say about your class?**

What do you think?

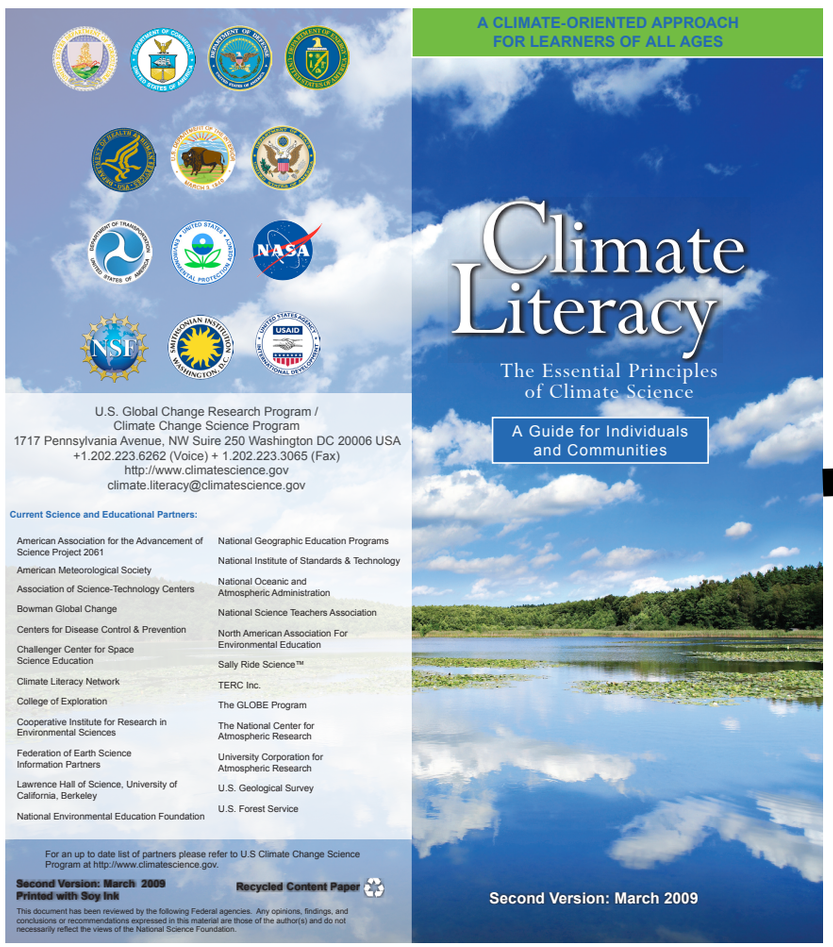
- **What was the most important thing you learned in that class?**
- **What would your students say about your class?**
- **What do you *hope* they would say?**

Identifying Important Ideas

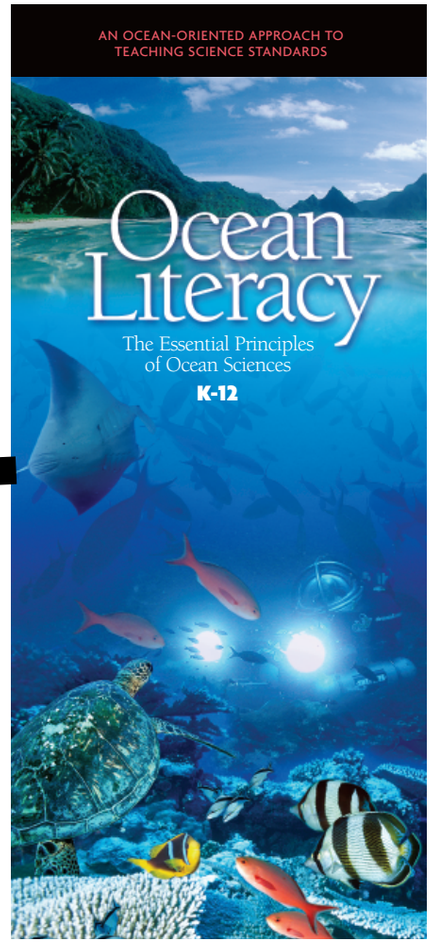




How can we synthesize?



Big Ideas from TFG/VFE Project



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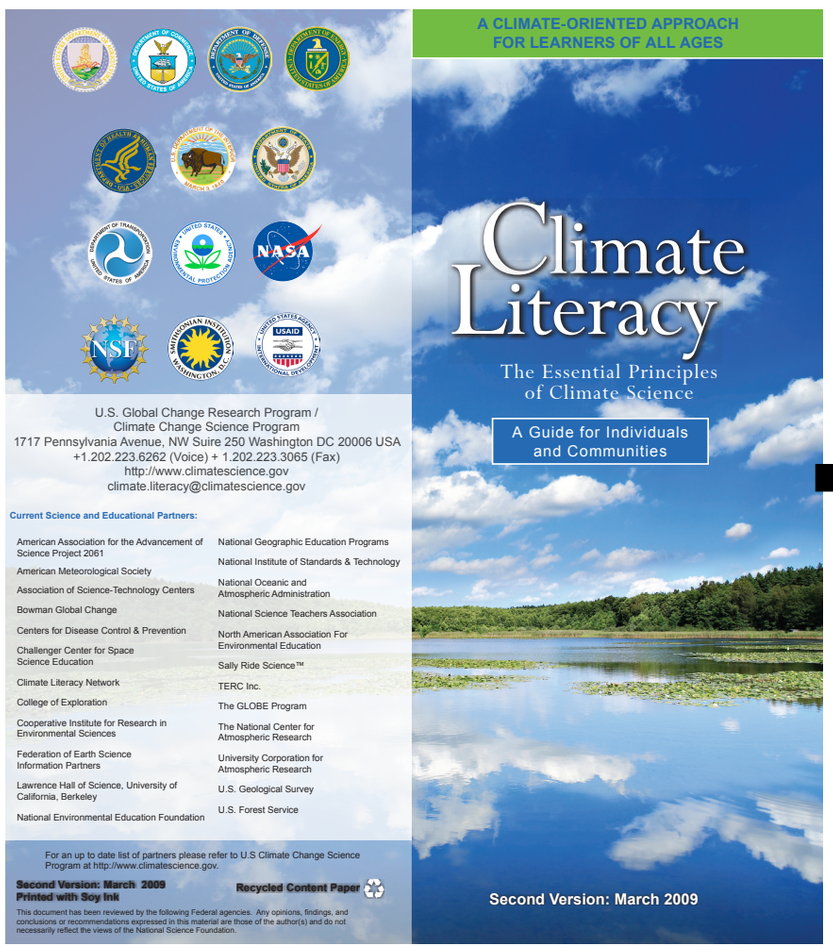
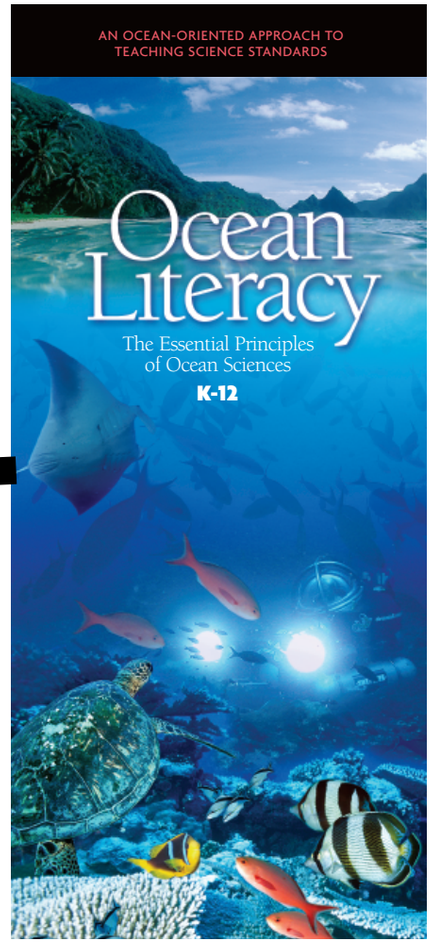


ReaLly Big Ideas from TFG/VFE Project



Where we are:

Essential Principles	Fundamental Concepts

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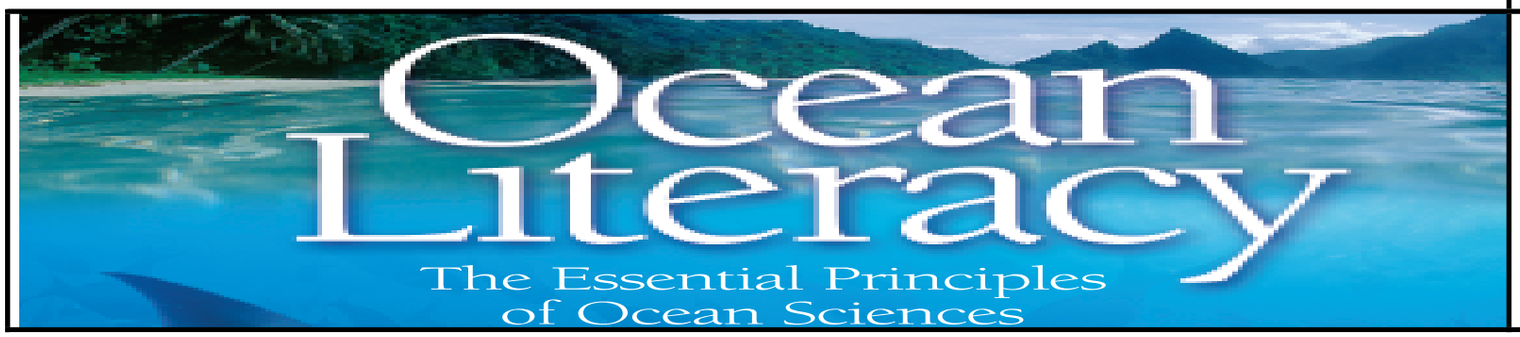
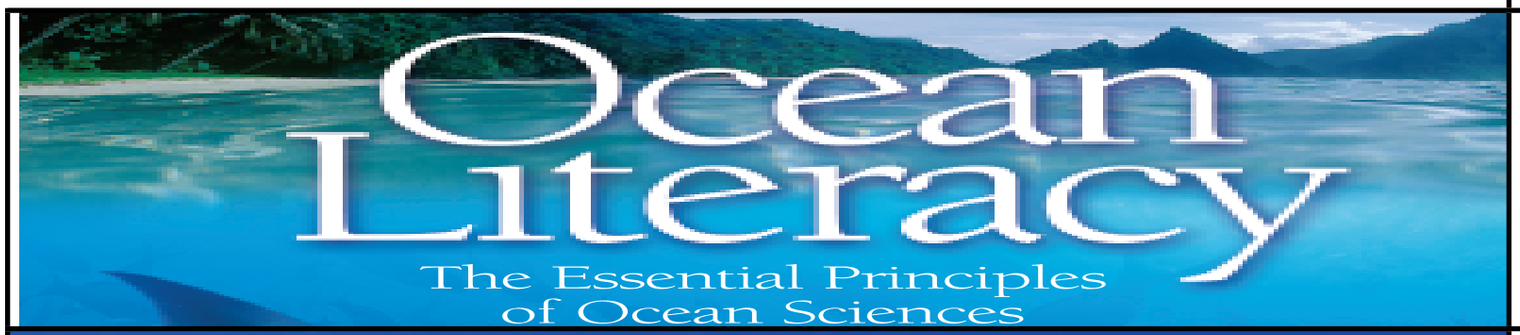
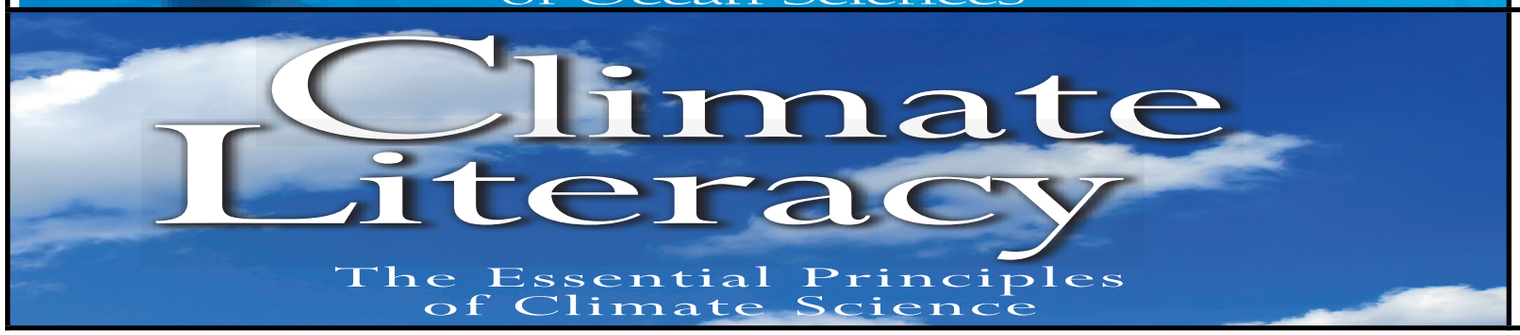


Essential Principles	Fundamental Concepts
7	44

Where we are:

	Essential Principles	Fundamental Concepts
	7	44
	8	47

Where we are:

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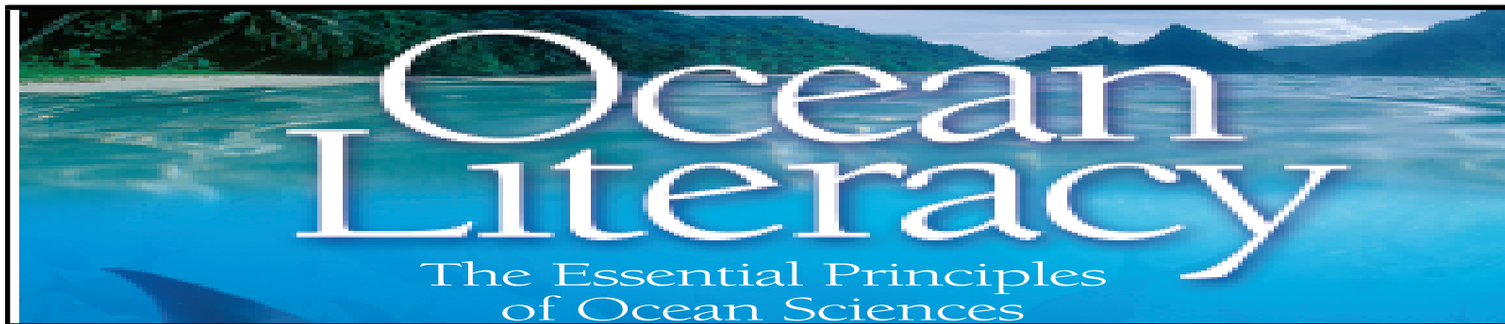
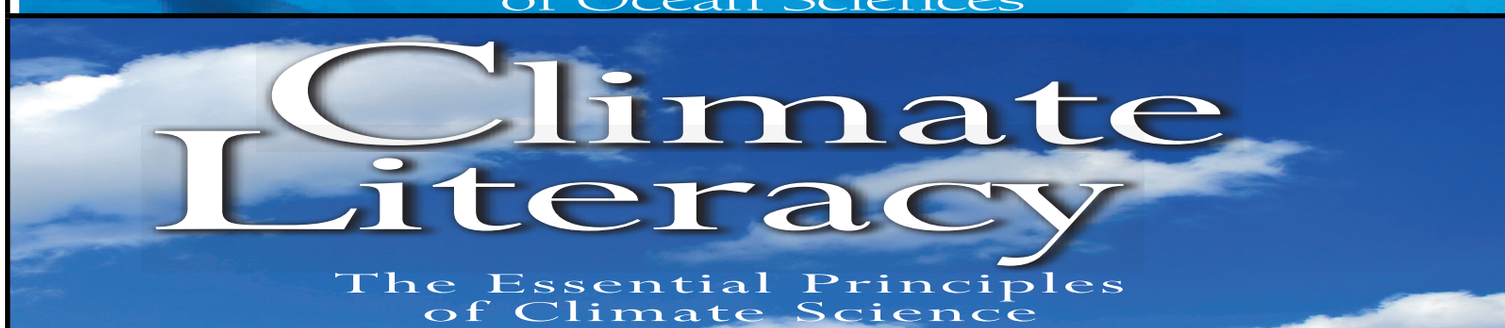
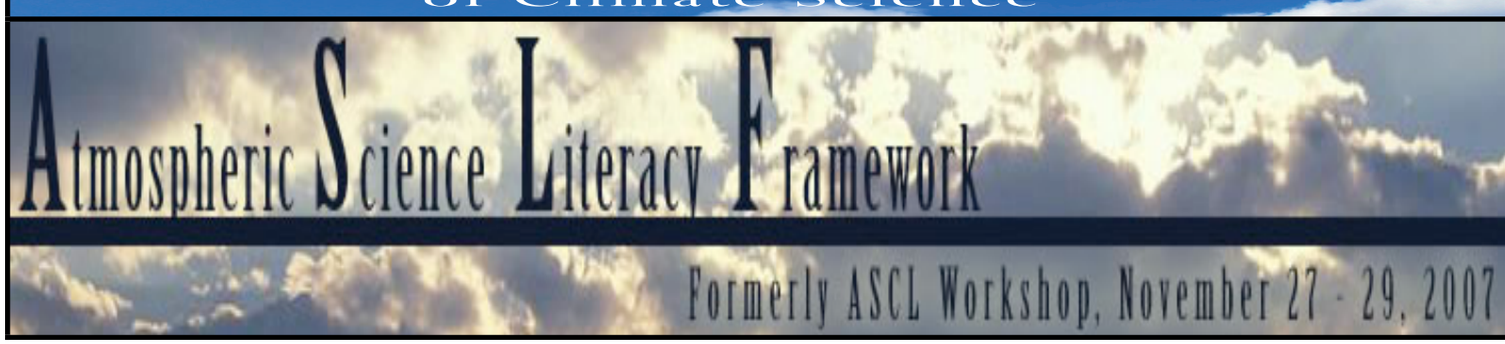
	7	44
	8	47
	7	33

Where we are:

	Essential Principles	Fundamental Concepts
Ocean Literacy: The Essential Principles of Ocean Sciences	7	44
Climate Literacy: The Essential Principles of Climate Science	8	47
Atmospheric Science Literacy Framework: Formerly ASCL Workshop, November 27 - 29, 2007	7	33
Earth Science Literacy Initiative	9	75

Where we are:

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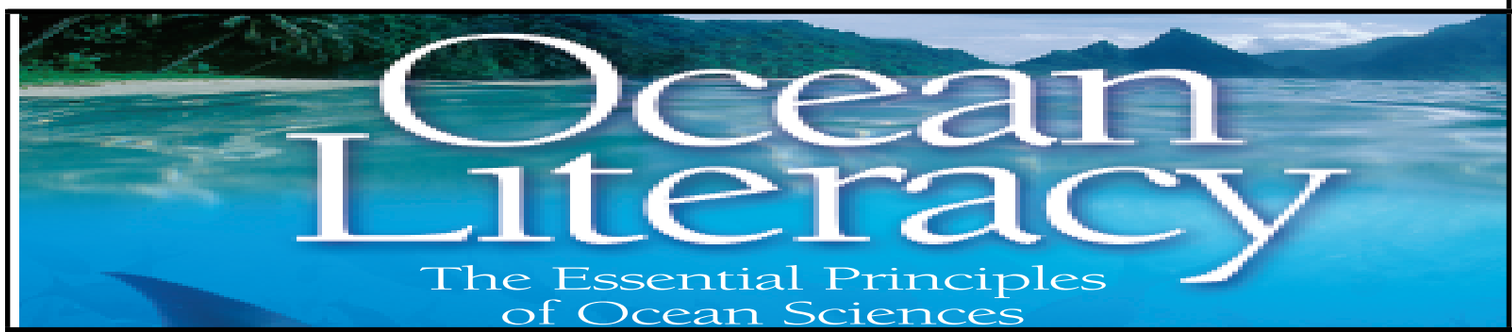
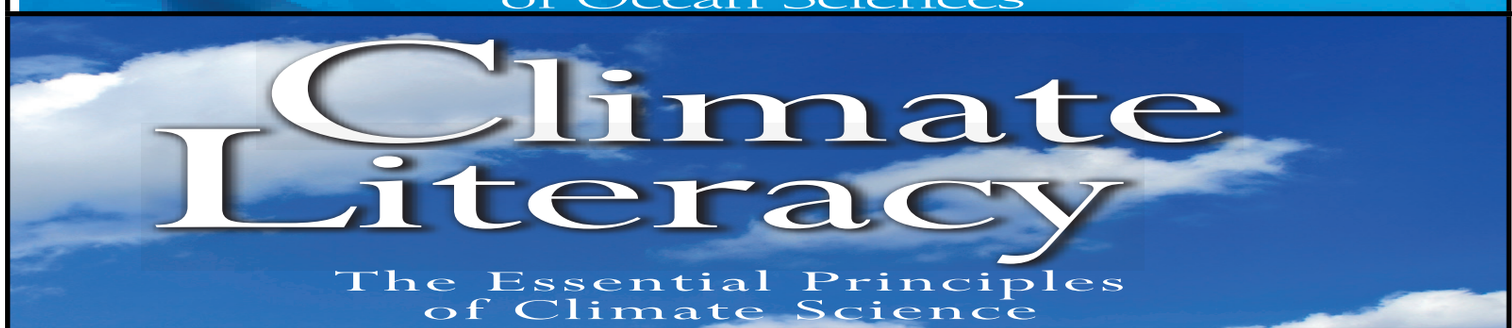
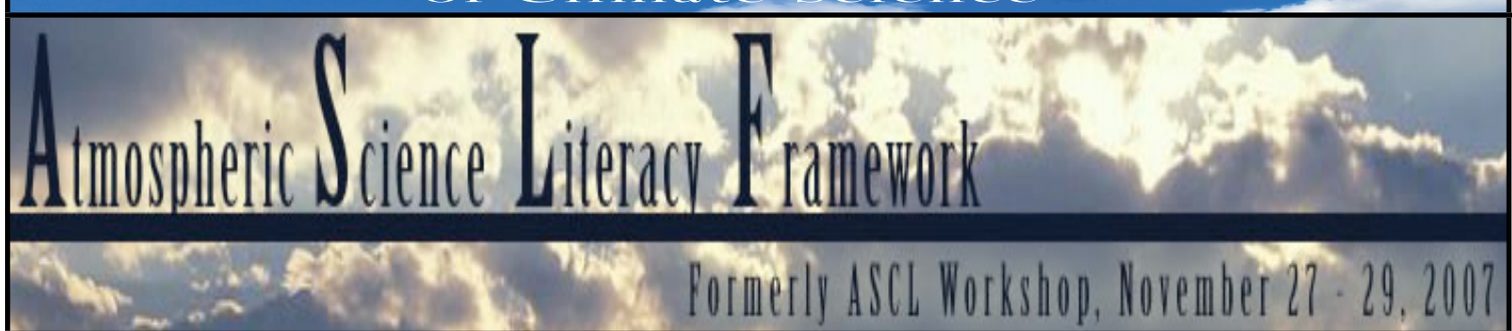
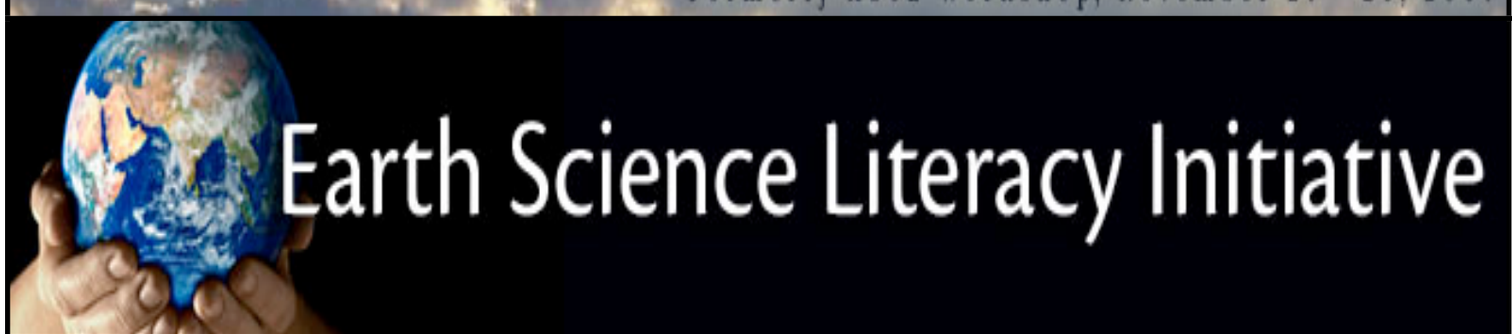
	7	44
	8	47
	7	33
	9	75
TOTAL	**31**	**198**

And, we haven't included:

And, we haven't included:

- Astronomy...

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- Astronomy...
- ...which is typically taught in the ***one*** high school course that addresses oceanography, climatology, meteorology, & geology.

We need to attend to the realities of school

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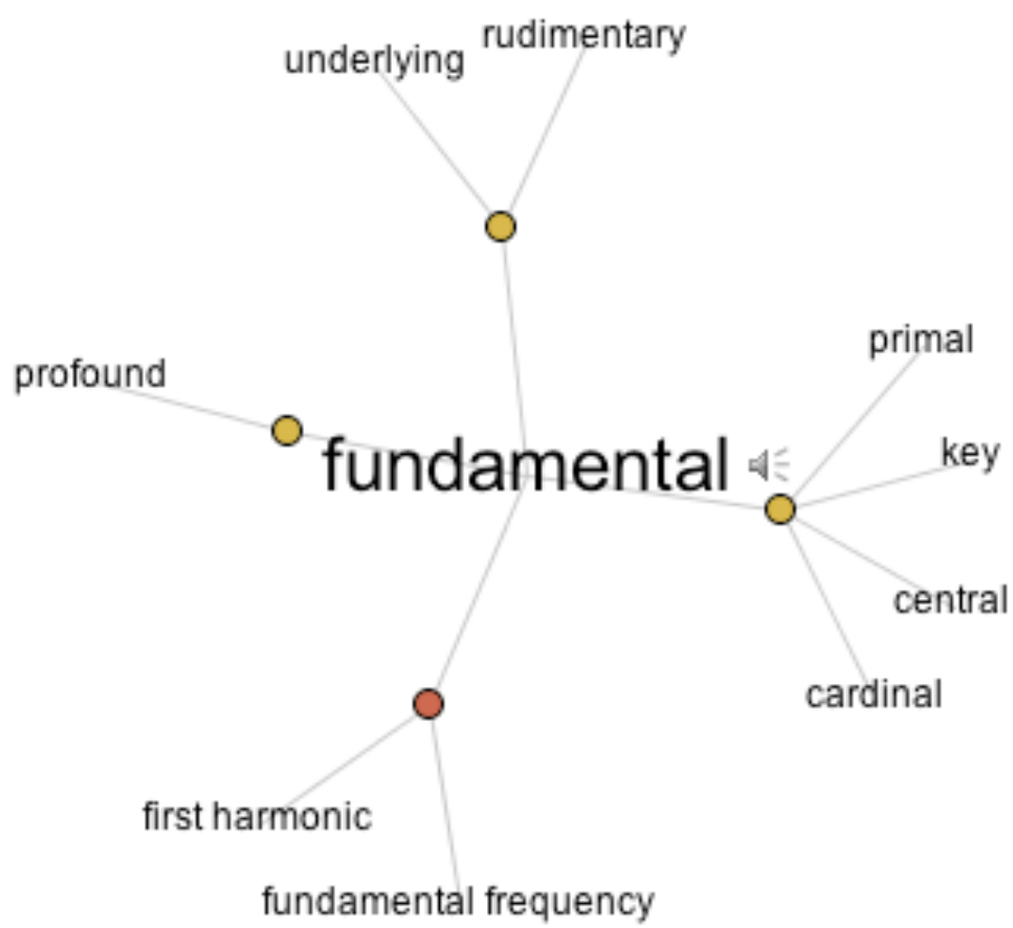
- Physics, chemistry & biology dominate high school science (and have for 100 years).
- *If* Earth systems science is taught, astronomy is usually included in the same one year course.

So, we have around 200 fundamental concepts...



...to teach in 180 days of instruction.

Good luck with that!

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Less is

more.

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Less is

better.

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- The typical curriculum in MS & HS science or math addresses more than thirty major concepts in a year.
- In Japan, about seven…
- Can we frame a small set of ideas that encompasses all that we would hope everyone would understand in the discipline?

Why small?

To develop competence in an area of inquiry, students must:

- have a deep foundation of factual knowledge,
- understand facts and ideas in the context of a conceptual framework, and
- organize knowledge in ways that facilitate retrieval and application.

(NRC committee on How People Learn)

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- Furthermore, the entire Earth Science curriculum is represented by this (small) set of ideas.

One ***suggested*** set of colossal ideas:

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- **To understand (deep) space and time, models and maps are necessary.**

All of this backgrounded by:

All of this backgrounded by:

How do we know what we know?

All of this backgrounded by:

How do we know what we know?

How does what we know inform our decision making?

Related to 2061's Common Themes:

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Systems

Related to 2061's Common Themes:

- Systems
- Models

Related to 2061's Common Themes:

- Systems
- Models
- Constancy & Change

Related to 2061's Common Themes:

- Systems
- Models
- Constancy & Change
- Scale

Overarching Questions:

How do we know what we know? How does what we know inform our decision-making?

Earth System Science Profound Ideas

The Earth is a System of Systems.	The Flow of Energy Drives the Cycling of Matter.	Life, including human life, influences and is influenced by the environment.	Physical and chemical principles are unchanging and drive both gradual and rapid changes in the Earth system.	To Understand (Deep) Time and the Scale of Space, Models and Maps are Necessary.
The Earth System is composed of and part of a multitude of systems, which cycle and interact resulting in dynamic equilibrium (though the system evolves). The Earth is also nested in larger systems including the solar system and the universe. However there is an inherent unpredictability in systems, which are composed of an (effectively) infinite number of interacting parts that follow simple rules. Each system is qualitatively different from, but not necessarily greater than the sum of its parts.	The Earth is an open system – it is the constant flow of solar radiation that powers most surface Earth processes and drives the cycling of most matter at or near the Earth's surface. Earth's internal heat is a driving force below the surface. Energy flows and cycles through the Earth system. Matter cycles within it. Convection drives weather and climate, ocean currents, the rock cycle and plate tectonics.	Photosynthetic bacteria reformulated the atmosphere making Earth habitable. Humans have changed the lay of the land, altered the distribution of flora and fauna and are changing atmospheric chemistry in ways that alter the climate. Earth system processes affect where and how humans live. For example, many people live in the shadow of volcanoes because of the fertile farmland found there, however they must keep a constant vigil to maintain their safety. The human impact on the environment is growing as population increases and the use of technology expands.	Earth processes (erosion, evolution or plate tectonics, for example) operating today are the same as those operating since they arose in Earth history and they are obedient to the laws of chemistry and physics. While the processes constantly changing the Earth are essentially fixed, their rates are not. Tipping points are reached that can result in rapid changes cascading through Earth systems.	The use of models is fundamental to all of the Earth Sciences. Maps and models aid in the understanding of aspects of the Earth system for which direct observation is not possible. Models assist in the comprehension of time and space at both immense and sub-microscopic scales. When compared to the size and age of the universe, humanity is a speck in space and a blip in time.

Earth Science Bigger Ideas & Overarching Questions

Overarching Questions:

How do we know what we know?

How does what we know inform our decision-making?

Earth is a system of systems.

Earth Science Bigger Ideas & Overarching Questions

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Does each idea cut across the entire Earth science curriculum?

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Is understanding of the idea attainable by students and does the understanding hold promise for retention?

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Is each idea essential to understanding a variety of topics?

Overarching Questions:

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Earth is a system of systems.	**The flow of energy drives the cycling of matter.**	**Life, including human life, influences and is influenced by the environment.**	**Physical and chemical principles are unchanging and drive both gradual and rapid changes in the Earth system.**	**To understand (deep) space and time, models and maps are necessary.**

Does each idea require uncoverage/have a bottomless quality?

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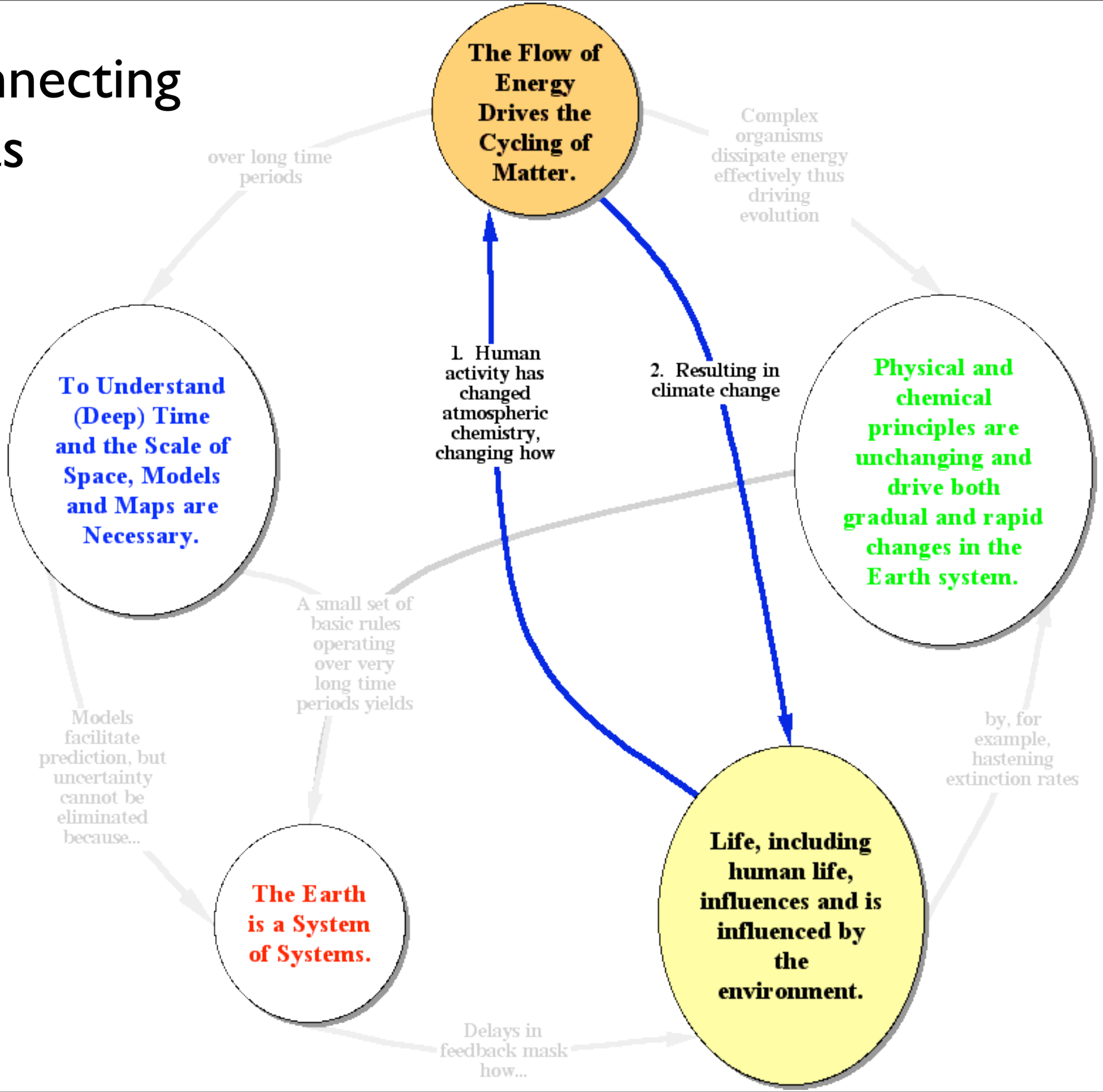
Earth is a system of systems.	**The flow of energy drives the cycling of matter.**	**Life, including human life, influences and is influenced by the environment.**	**Physical and chemical principles are unchanging and drive both gradual and rapid changes in the Earth system.**	**To understand (deep) space and time, models and maps are necessary.**

Is the entire Earth science curriculum represented by this (small) set of ideas?

Connecting Ideas



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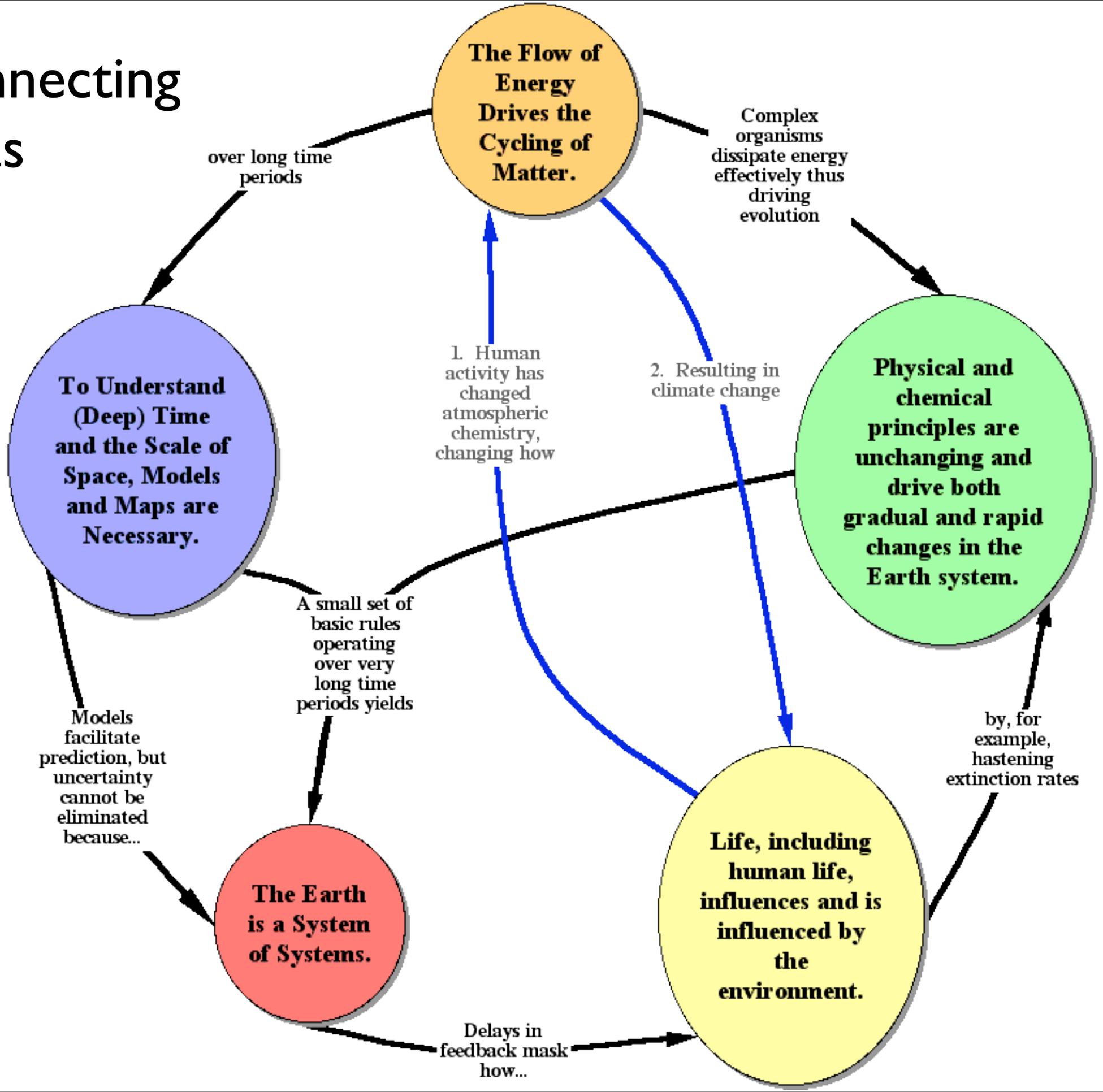

How does this set compare to the existing principles?

Overarching Questions:
How do we know what we know? How does what we know inform our decision making?

Bigger Ideas
Earth is a system of systems.
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Overarching Questions:

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Bigger Ideas	Ocean
Earth is a system of systems.	The ocean is a major influence on weather and climate.
The flow of energy drives the cycling of matter.	The ocean supports a great diversity of life and ecosystems.
Life, including human life, influences and is influenced by the environment.	The ocean makes Earth habitable.
	The ocean and humans are inextricably interconnected.
Physical and chemical principles are unchanging and drive both gradual and rapid changes in the Earth system.	The ocean and life in the ocean shape the features of the Earth.
To understand (deep) space and time, models and maps are necessary.	The Earth has one big ocean with many features.
	The ocean is largely unexplored.

Overarching Questions:
How do we know what we know? How does what we know inform our decision making?

Bigger Ideas	Ocean	Climate
Earth is a system of systems.	The ocean is a major influence on weather and climate.	Climate is regulated by complex interactions among components of the Earth system.
The flow of energy drives the cycling of matter.	The ocean supports a great diversity of life and ecosystems.	Life on Earth depends on, has been shaped by, and affects climate.
Life, including human life, influences and is influenced by the environment.	The ocean makes Earth habitable.	The Sun is the primary source of energy for Earth's climate system.
Physical and chemical principles are unchanging and drive both gradual and rapid changes in the Earth system.	The ocean and humans are inextricably interconnected.	Climate change will have consequences for the Earth system and human lives.
To understand (deep) space and time, models and maps are necessary.	The ocean and life in the ocean shape the features of the Earth.	Human activities are impacting the climate system.
	The Earth has one big ocean with many features.	**Humans can take actions to reduce climate change and its impacts.**
	The ocean is largely unexplored.	Climate varies over space and time through both natural and man-made processes.
		Our understanding of the climate system is improved through observation, theoretical studies and

Overarching Questions:
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Bigger Ideas	Climate
Earth is a system of systems.	Climate is regulated by complex interactions among components of the Earth system.
The flow of energy drives the cycling of matter.	Life on Earth depends on, has been shaped by, and affects climate.
Life, including human life, influences and is influenced by the environment.	The Sun is the primary source of energy for Earth's climate system.
Physical and chemical principles are unchanging and drive both gradual and rapid changes in the Earth system.	Climate change will have consequences for the Earth system and human lives.
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Overarching Questions:
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Bigger Ideas	Atmosphere
Earth is a system of systems.	Earth's atmosphere continuously interacts with the other components of the Earth System.
The flow of energy drives the cycling of matter.	Energy from the Sun drives atmospheric processes.
	Atmospheric circulations transport matter and energy.
Life, including human life, influences and is influenced by the environment.	Earth's atmosphere and humans are inextricably linked.
	Earth has a thin atmosphere that sustains life.
Physical and chemical principles are unchanging and drive both gradual and rapid changes in the Earth system.	Earth's atmosphere changes over time and space, giving rise to weather and climate.
To understand (deep) space and time, models and maps are necessary.	We seek to understand the past, present, and future behavior of Earth's atmosphere through scientific observation and reasoning.

Overarching Questions:
How do we know what we know? How does what we know inform our decision making?

Bigger Ideas	Earth Science
Earth is a system of systems.	Earth is a complex system of interacting rock, water, air, and life.
The flow of energy drives the cycling of matter.	Humans significantly alter the Earth.
	Humans depend on Earth for resources.
Life, including human life, influences and is influenced by the environment.	Natural hazards pose risks to humans.
	Earth scientists use repeatable observations and testable ideas to understand and explain our planet.
Physical and chemical principles are unchanging and drive both gradual and rapid changes in the Earth system.	Life evolves on a dynamic Earth and continuously modifies Earth.
	Earth is continually changing.
To understand (deep) space and time, models and maps are necessary.	Earth is 4.6 billion years old.
	Earth is the water planet.

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Bigger Ideas	Ocean	Climate	Atmosphere	Earth Science
Earth is a system of systems.	The ocean is a major influence on weather and climate.	Climate is regulated by complex interactions among components of the Earth system.	Earth's atmosphere continuously interacts with the other components of the Earth System.	Earth is a complex system of interacting rock, water, air, and life.
The flow of energy drives the cycling of matter.	The ocean supports a great diversity of life and ecosystems.	Life on Earth depends on, has been shaped by, and affects climate.	Energy from the Sun drives atmospheric processes.	Humans significantly alter the Earth.
Life, including human life, influences and is influenced by the environment.	The ocean makes Earth habitable.	The Sun is the primary source of energy for Earth's climate system.	Atmospheric circulations transport matter and energy.	Humans depend on Earth for resources.
Physical and chemical principles are unchanging and drive both gradual and rapid changes in the Earth system.	The ocean and humans are inextricably interconnected.	Climate change will have consequences for the Earth system and human lives.	Earth's atmosphere and humans are inextricably linked.	Natural hazards pose risks to humans.
To understand (deep) space and time, models and maps are necessary.	The ocean and life in the ocean shape the features of the Earth.	Human activities are impacting the climate system.	Earth has a thin atmosphere that sustains life.	Earth scientists use repeatable observations and testable ideas to understand and explain our planet.
	The Earth has one big ocean with many features.	**Humans can take actions to reduce climate change and its impacts.**	Earth's atmosphere changes over time and space, giving rise to weather and climate.	Life evolves on a dynamic Earth and continuously modifies Earth.
	The ocean is largely unexplored.	Climate varies over space and time through both natural and man-made processes.	We seek to understand the past, present, and future behavior of Earth's atmosphere through scientific observation and reasoning.	Earth is continually changing.
		Our understanding of the climate system is improved through observation, theoretical studies and		Earth is 4.6 billion years old.
				Earth is the water planet.

So what?

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- What does this mean for teaching?
- What do you think?
- These typically aren't units one would or should teach.
- How will teachers revisit these ideas again and again?
- What would be evidence that someone understands these ideas?

Know that it's really hard.

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...like many things about teaching well.

One simple recommendation:

Identify a few ideas that you think are really important and let your students know you think these ideas are really important!

Assembling Tools & Materials

"Science is made up of facts like a house is made of bricks, but a pile of facts does not make science nor a pile of bricks a house”

~Henri Poincare

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We need to rethink:

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We need to rethink:

- How we teach.
- What we teach.

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- What we teach.
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Focusing on ReaLly big ideas can help with all of that.

New National Standards are in Development.

- I'm on the Earth & Space Science Design Committee.
- We've just begun the work, but it will emphasize more of the kind of thinking expressed today than is in the current standards.

Wrapping up...

- There's more about these ideas here:

- Follow the link for Big Ideas.

Questions?

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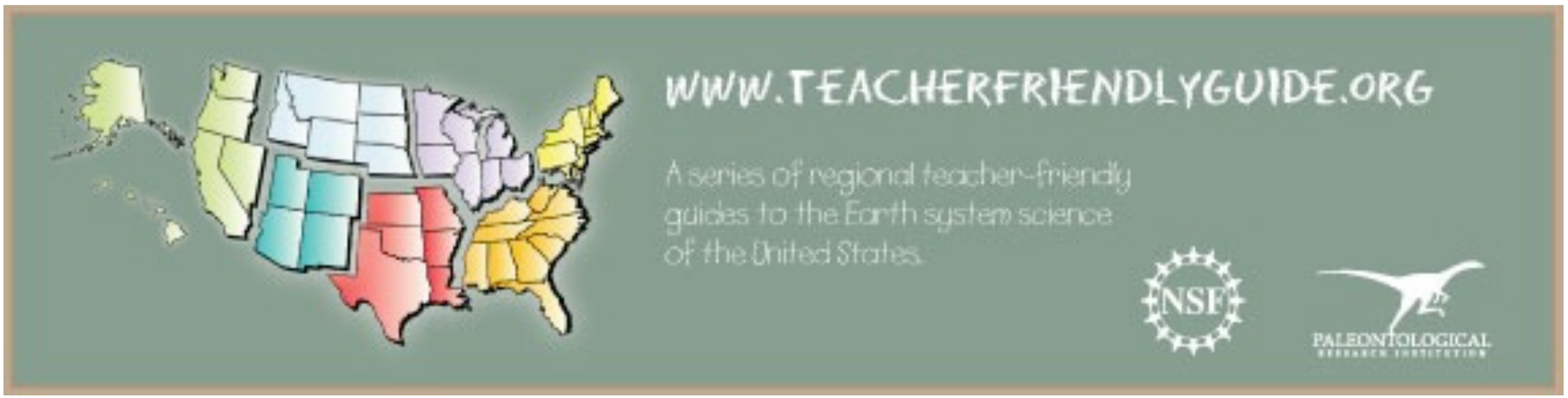

Bonus material

Essential Questions

- See Sarah Miller's matrix.

Essential Questions
Intro
Surface Processes
Earth History & Plate Tectonics
Meteorology
Climate
Astronomy

Overarching Questions:

How do we know what we know? How does what we know inform our decision-making?

Earth System Science Profound Ideas

The Earth is a System of Systems.	The Flow of Energy Drives the Cycling of Matter.	Life, including human life, influences and is influenced by the environment.	Physical and chemical principles are unchanging and drive both gradual and rapid changes in the Earth system.	To Understand (Deep) Time and the Scale of Space, Models and Maps are Necessary.
The Earth System is composed of and part of a multitude of systems, which cycle and interact resulting in dynamic equilibrium (though the system evolves). The Earth is also nested in larger systems including the solar system and the universe. However there is an inherent unpredictability in systems, which are composed of an (effectively) infinite number of interacting parts that follow simple rules. Each system is qualitatively different from, but not necessarily greater than the sum of its parts.	The Earth is an open system – it is the constant flow of solar radiation that powers most surface Earth processes and drives the cycling of most matter at or near the Earth's surface. Earth's internal heat is a driving force below the surface. Energy flows and cycles through the Earth system. Matter cycles within it. Convection drives weather and climate, ocean currents, the rock cycle and plate tectonics.	Photosynthetic bacteria reformulated the atmosphere making Earth habitable. Humans have changed the lay of the land, altered the distribution of flora and fauna and are changing atmospheric chemistry in ways that alter the climate. Earth system processes affect where and how humans live. For example, many people live in the shadow of volcanoes because of the fertile farmland found there, however they must keep a constant vigil to maintain their safety. The human impact on the environment is growing as population increases and the use of technology expands.	Earth processes (erosion, evolution or plate tectonics, for example) operating today are the same as those operating since they arose in Earth history and they are obedient to the laws of chemistry and physics. While the processes constantly changing the Earth are essentially fixed, their rates are not. Tipping points are reached that can result in rapid changes cascading through Earth systems.	The use of models is fundamental to all of the Earth Sciences. Maps and models aid in the understanding of aspects of the Earth system for which direct observation is not possible. Models assist in the comprehension of time and space at both immense and sub-microscopic scales. When compared to the size and age of the universe, humanity is a speck in space and a blip in time.

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Big Ideas	Essential Questions
The Earth System is a Complex System.	How can recognizing and understanding feedback and patterns help you figure out what's going on in the Earth System?
The Flow of Energy Drives the Cycling of Matter	Why does the Earth look the way it does?
Humans and the Environment Impact Each Other.	How do I fit in with all of Earth's parts?
Evolution and Uniformity Define the Earth System.	How has the Earth changed over time? (What does the evolution of life have to do with that?) How does the past help us predict the future?
To Understand (Deep) Time and the Scale of Space, Models and Maps are Necessary.	What makes a good model?
Nature of science	How do we know what we know?

Big Ideas	Unit: Introduction
The Earth System is a Complex System.	How can maps and models be used to understand interactions on earth?
The Flow of Energy Drives the Cycling of Matter	How can we predict if something will float or sink?
Humans and the Environment Impact Each Other.	How do I fit in with all of Earth's parts?
Evolution and Uniformity Define the Earth System.	How does the past help us predict the future?
To Understand (Deep) Time and the Scale of Space, Models and Maps are Necessary.	What makes a good model of Earth?
Nature of science	How do we know what we know?

Big Ideas	Unit: Surface Processes
The Earth System is a Complex System.	How does the interaction of air, water and earth shape the surface?
The Flow of Energy Drives the Cycling of Matter	Why does the Chenango Valley look the way it looks?
Humans and the Environment Impact Each Other.	How do humans change the Earth's surface?
Evolution and Uniformity Define the Earth System.	Why does Earth's surface look the way it does?
To Understand (Deep) Time and the Scale of Space, Models and Maps are Necessary.	How can erosional/ depositional systems be modeled?
Nature of science	How do we know what we know?

Big Ideas	Earth History & Plate Tectonics
The Earth System is a Complex System.	What connections are there between the changing surface of the earth and the evolution of life?
The Flow of Energy Drives the Cycling of Matter	Are the continents really moving?
Humans and the Environment Impact Each Other.	How does the movement of the Earth's crust affect me?
Evolution and Uniformity Define the Earth System.	How do we know how old the Earth is?
To Understand (Deep) Time and the Scale of Space, Models and Maps are Necessary.	How can an earthquake be modeled?
Nature of science	How do we know what we know?

Big Ideas	Unit: Meteorology
The Earth System is a Complex System.	How does a cloud form?
The Flow of Energy Drives the Cycling of Matter	What would the world be like without convection?
Humans and the Environment Impact Each Other.	How does the weather affect me?
Evolution and Uniformity Define the Earth System.	Why do we have the weather we have?
To Understand (Deep) Time and the Scale of Space, Models and Maps are Necessary.	How do we make weather forecasts?
Nature of science	How do we know what we know?

Big Ideas	Unit: Climate
The Earth System is a Complex System.	What interactions create our climate? How are they changing?
The Flow of Energy Drives the Cycling of Matter	What the world be like without convection?
Humans and the Environment Impact Each Other.	What effect do I have on the climate?
Evolution and Uniformity Define the Earth System.	What can we learn from past climates?
To Understand (Deep) Time and the Scale of Space, Models and Maps are Necessary.	What factors have to go into a good climate model?
Nature of science	How do we know what we know?

Big Ideas	Astronomy
The Earth System is a Complex System.	What patterns can be found in the sky?
The Flow of Energy Drives the Cycling of Matter	Why do we have seasons?
Humans and the Environment Impact Each Other.	What does the life cycle of a star have to do with me?
Evolution and Uniformity Define the Earth System.	Why do we think the Universe is old?
To Understand (Deep) Time and the Scale of Space, Models and Maps are Necessary.	How big is space?
Nature of science	How do we know what we know?