Developing a Framework for Climate Literacy:

The Case for Climate Literacy in the 21st Century

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Climate Program Office,
Washington, D.C., USA

A Private Universe Project

How well do US college graduates understand important science ideas?

1. A seed grows into a large tree. Where did the mass of the tree come from?
2. What if I told you that the mass comes mainly from the carbon dioxide in the air?

Climate Literacy

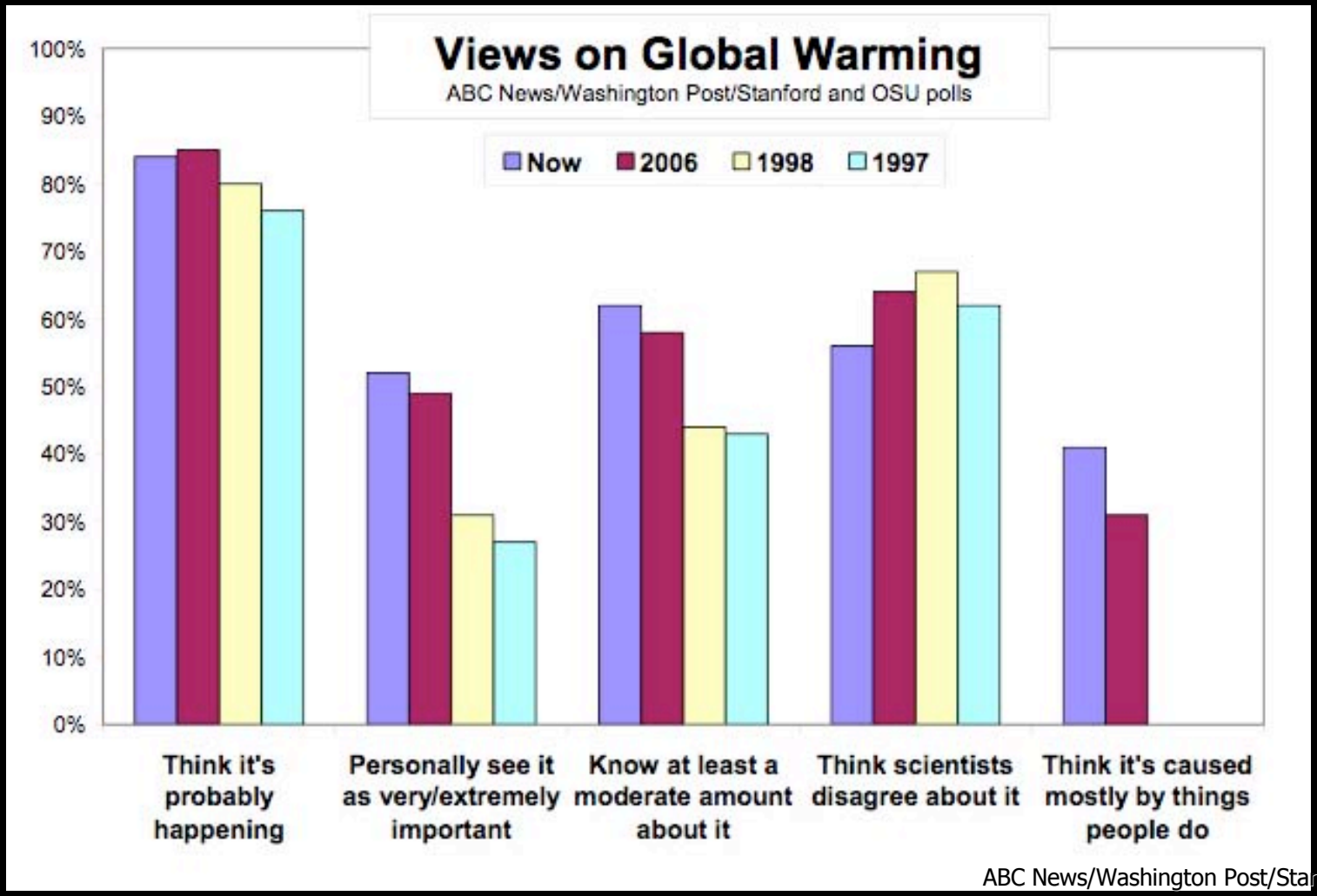
What does a climate literate citizen look like?

How would a climate literate citizen make informed decisions?

How can the we assist in ensuring climate literate citizens?

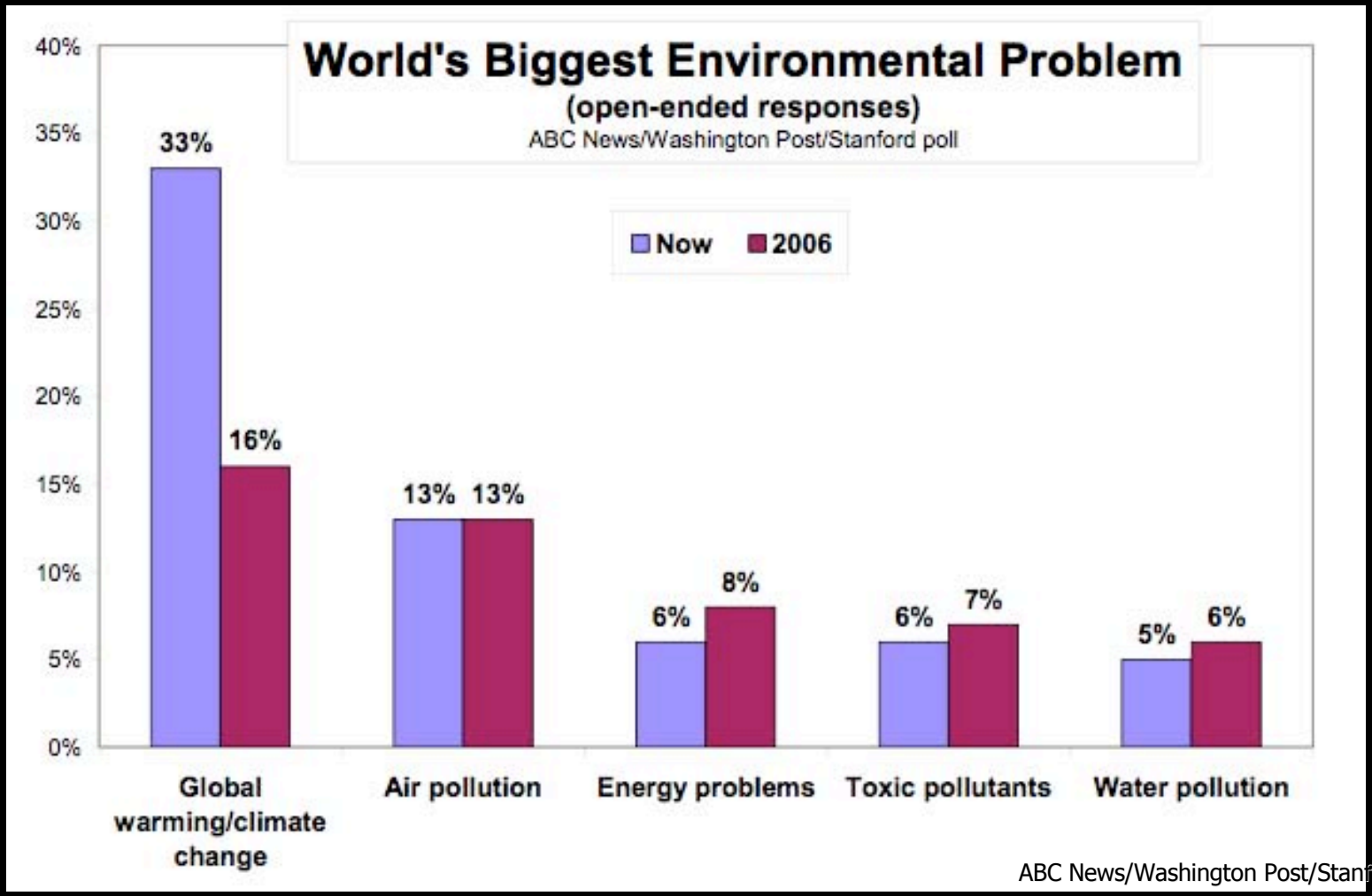
How can the we inform the climate literate citizen's decisions?

Where Is The Public?



ABC News/Washington Post/Stanford and OSU

Where Is The Public?



ABC News/Washington Post/Stanford and OSU

Effective Communications about Global Warming

Existence

Attitudes

Certainty

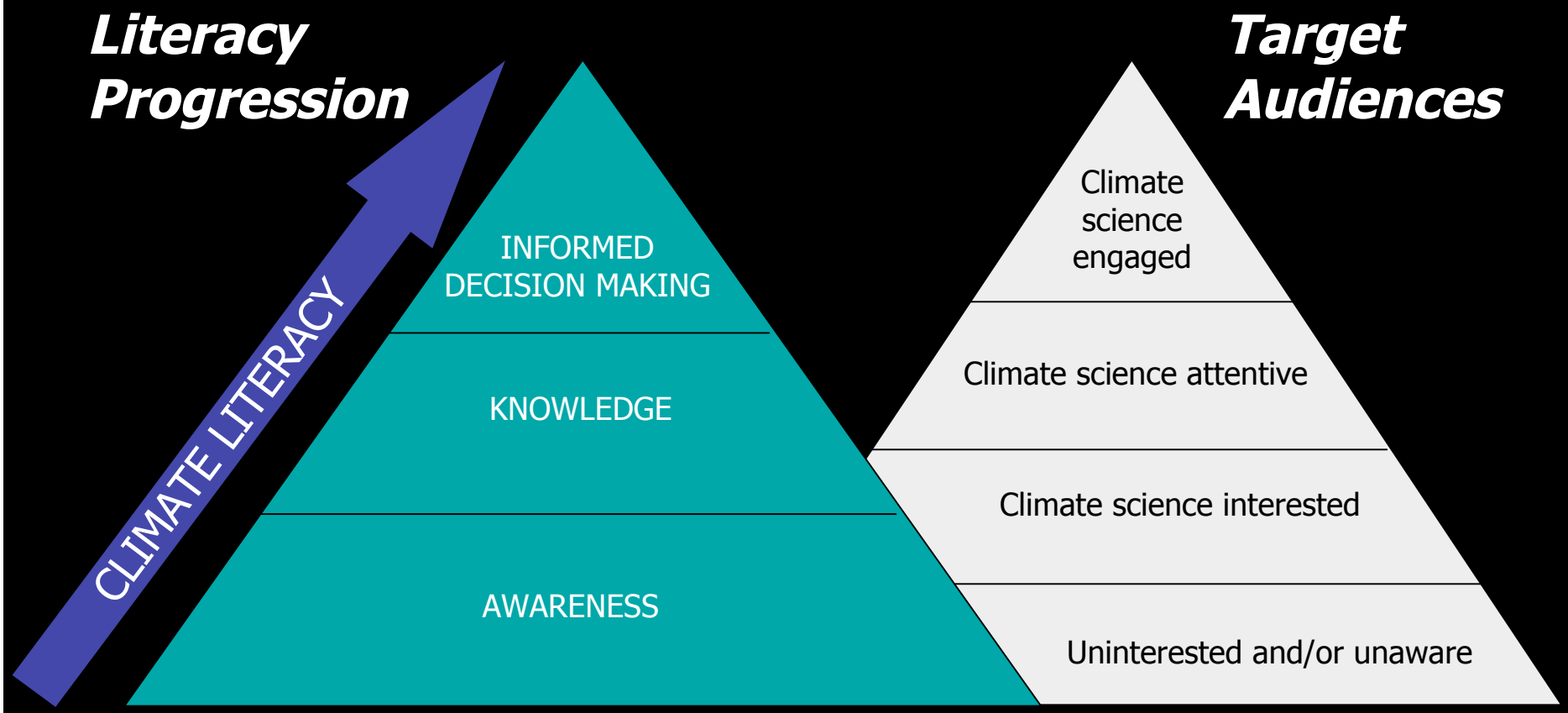
Human Responsibility

People's Ability To Remedy It

J. Krosnick, 2006, Stanford

Climate Literacy is…

- **…a continuum of competency**



Long-term, the vision expects a society capable of informed decision-making

ATLAS OF SCIENCE LITERACY

VOLUME 2

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

PROJECT 2061

ATLAS OF SCIENCE LITERACY, VOLUME 1 AND VOLUME 2

COMBINED TABLE OF CONTENTS

Titles and page numbers printed in green indicate maps in Volume 2; those printed in gray indicate maps in Volume 1.

Communicating and Learning About Global Climate Change

An Abbreviated Guide for Teaching Climate Change, from Project 2061 at AAAS

©Lonnie Thompson/Ohio State University

Project 2061 AAAS

- WEATHER AND CLIMATE
- USE OF EARTH'S RESOURCES
- ENERGY RESOURCES
- INTERDEPENDENCE OF LIFE
- SCIENTIFIC INVESTIGATIONS
- INTERACTION OF TECHNOLOGY AND SOCIETY
- DECISIONS ABOUT USING TECHNOLOGY
- PATTERNS OF CHANGE
- MORE TO COME…

WEATHER AND CLIMATE (4B)

The earth has a variety of climatic patterns, which consist of different conditions of temperature, precipitation, humidity, wind, air pressure, and other atmospheric phenomena. These result from a variety of factors. Climate and changes in climate have influenced in the past and will continue to influence what kinds of life forms are able to exist. Understanding the basic principles that contribute to maintaining and causing changes in weather and climate increases our ability to forecast and moderate the effects of weather and to make informed decisions about human activities that may contribute to climate change.

The map is organized around four strands—*temperature and winds, water cycle, atmosphere,* and *climate change*. The progression of understanding begins in the elementary grades with observations about heat transfer, changes in water from one state to another, and changes in weather over the course of a day and over the course of seasons. By middle school, the focus is on the water cycle, patterns of change in temperature, and the notion of climate change. In high school, seasons and winds and the water cycle are related to gravity and the earth's rotation, and climate change is related to natural causes and human activities.

Benchmarks in this map about temperature and winds draw on ideas about heat transfer and transformation in the **ENERGY TRANSFORMATIONS** map. Benchmarks in the *climate change* strand are also related to the **SCIENCE AND SOCIETY** map. The widespread use of climate models to improve our understanding of the earth's climate system and climate change suggests a connection to benchmarks in the **MODELS** map as well.

NOTES

The left-hand side of the *temperature and winds* strand presents a progression of understanding of seasons. The explanation of the seasons in terms of the tilt of the earth requires students to engage in fairly complex spatial reasoning. For this reason, although the idea is introduced at the 6-8 grade level in *Benchmarks*, the map places it (4B/H3) at the 9-12 level.

Benchmarks related to the heating of materials and the transfer of thermal energy lay the conceptual groundwork for understanding solar heating, global circulation, seasonal weather patterns and climate, and the effect of greenhouse gases. To understand how thermal energy moves in both oceanic and atmospheric systems, students need to know that convective currents are an essential mechanism that aids in that movement. In middle school, understanding of convection currents is linked to experiences with relevant phenomena. Understanding convection in terms of gravity, buoyant forces, and pressure is not expected until high school. It is not necessary for students to have a molecular comprehension of thermal energy to be able to understand atmospheric and oceanic circulation patterns and their role in climate.

Several lines of conceptual development converge in the new 9-12 benchmark that begins "Climatic conditions result from…." These include an understanding of temperature patterns over the earth, atmospheric and oceanic circulation patterns, and the water cycle. A double-headed arrow between this benchmark and another new benchmark (4B/H6) on climate change indicates that they are closely related but that neither is conceptually dependent on the other.

RESEARCH IN *BENCHMARKS*

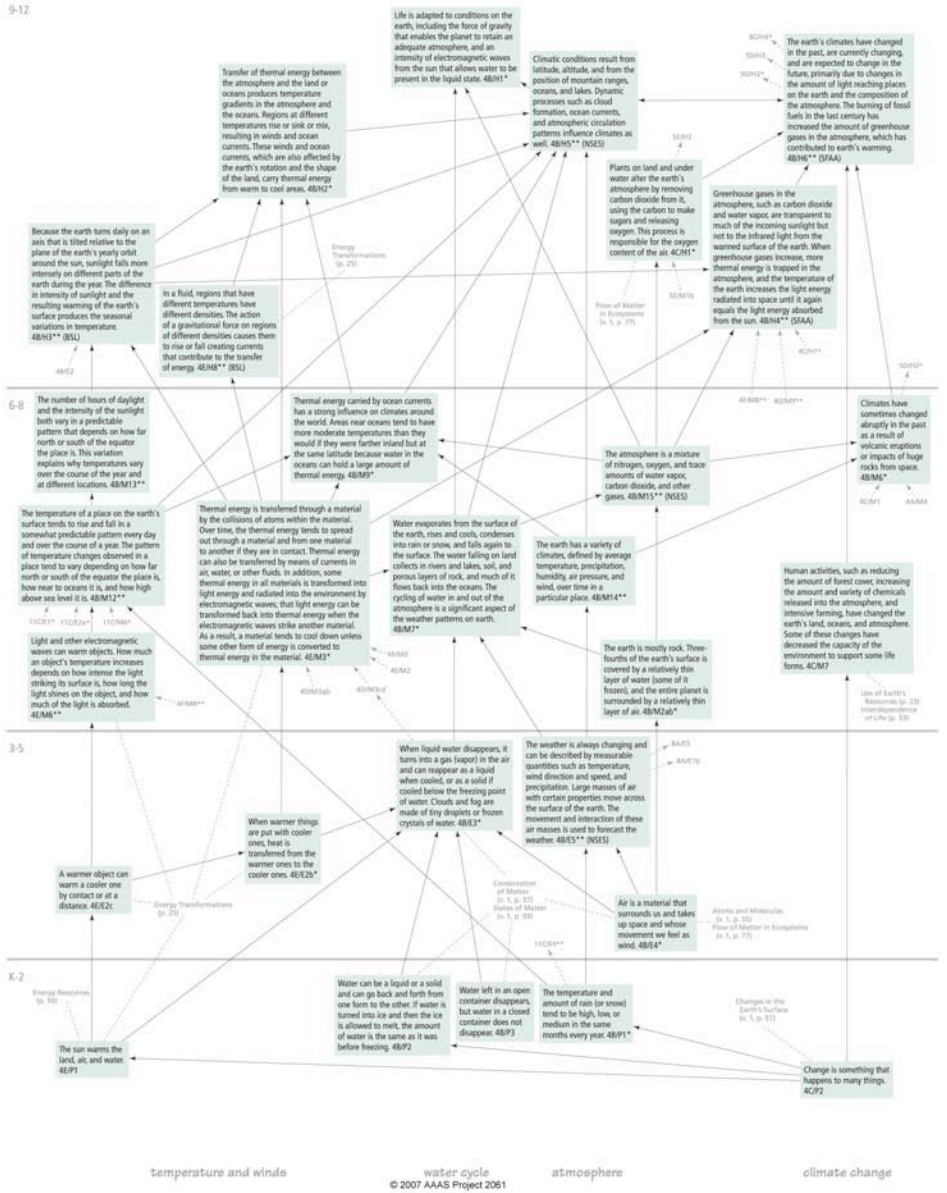
Students of all ages (including college students and adults) have difficulty understanding what causes the seasons. Students may not be able to understand explanations of the seasons before they reasonably understand the relative size, motion, and distance of the sun and the earth (Sadler, 1987; Vosniadou, 1991). Many students before and after instruction in earth science think that winter is colder than summer because the earth is farther from the sun in winter (Atwood & Atwood, 1996; Dove, 1998; Philips, 1991; Sadler, 1998). This idea is often related to the belief that the earth orbits the sun in an elongated elliptical path (Galili & Lavrik, 1998; Sadler, 1998). Other students, especially after instruction, think that the distance between the northern hemisphere and the sun changes because the earth leans toward the sun in the summer and away from the sun in winter (Galili & Lavrik, 1998; Sadler, 1998). Students' ideas about how light travels and about the earth-sun relationship, including the shape of the earth's orbit, the period of the earth's revolution around the sun, and the period of the earth's rotation around its axis, may interfere with students' understanding of the seasons (Galili & Lavrik, 1998; Saliemo, Edelson, & Sherin, 2005). For example, some students believe that the side of the sun not facing the earth experiences winter, indicating a confusion between the daily rotation of the earth and its yearly revolution around the sun (Salierno, Edelson, & Sherin, 2005).

Although upper elementary students may identify air as existing even in static situations and recognize that it takes space, recognizing that air has weight may be challenging even for high-school students (Sere, 1985; Driver et al., 1994a; Krnel, Watson, & Glazar, 1998). Students of all ages (including college students) may believe that air exerts force or pressure only when it is moving and only downwards (Driver et al., 1994a; Sere, 1985; Henriques, 2002; Nelson, Aron, & Francek, 1992). Only a few middle-school students use the idea of pressure differences between regions of the atmosphere to account for wind; instead, they may account for winds in terms of visible moving objects or the movement of the earth (Driver et al., 1994a).

Before students understand that water is converted to an invisible form, they may initially believe that when water evaporates it ceases to exist, or that it changes location but remains a liquid, or that it is transformed into some other perceptible form (fog, steam, droplets, etc.) (Bar, 1989; Russell, Harlen, & Watt, 1989; Russell & Watt, 1990; Krnel, Watson, & Glazar, 1998). With special instruction, some students in 5th grade may be able to identify the air as the final location of evaporating water (Russell & Watt, 1990), but they must first accept air as a permanent substance (Bar, 1989). For many students, difficulty understanding the existence of water vapor in the atmosphere persists in middle school years (Lee et al., 1993; Johnson, 1998). Students can understand rainfall in terms of gravity once they attribute weight to little drops of water (typically in upper elementary grades), but the mechanism through which condensation occurs may not be understood until high school (Bar, 1989).

Students of all ages may confuse the ozone layer with the greenhouse effect, and may have a tendency to imagine that all environmentally friendly actions help to solve all environmental problems (for example, that the use of unleaded petrol reduces the risk of global warming) (Andersson & Wallin, 2000; Koulaidis & Christidou, 1998; Meadows & Wiesenmayer, 1999; Rye, Rubba, & Wiesenmayer, 1997). Students have difficulty linking relevant elements of knowledge when explaining the greenhouse effect and may confuse the natural greenhouse effect with the enhancement of that effect (Andersson & Wallin, 2000).

See **ENERGY RESOURCES** and **ENERGY TRANSFORMATIONS** for additional research.



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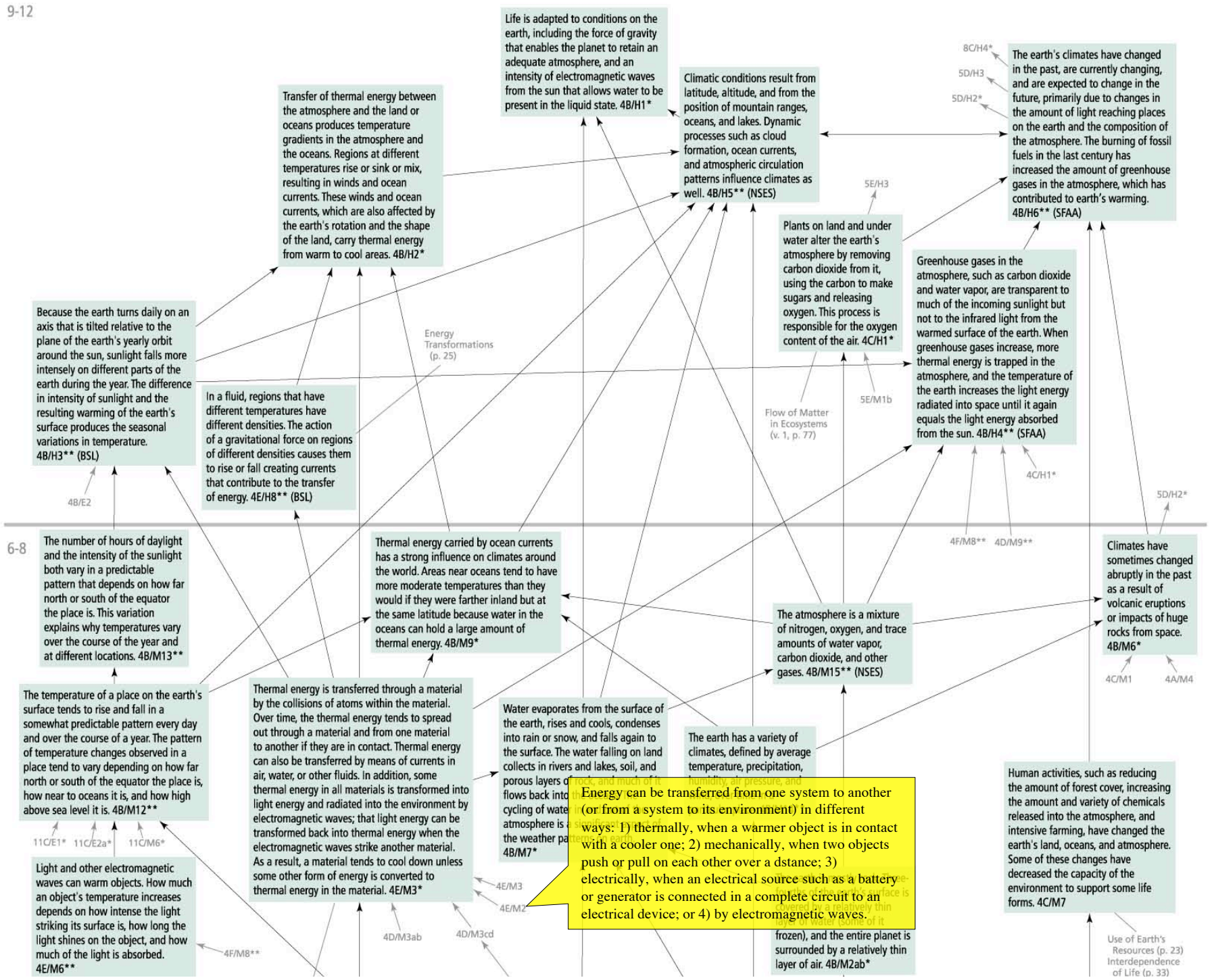

9-12
6-8
Life is adapted to conditions on the earth, including the force of gravity that enables the planet to retain an adequate atmosphere, and an intensity of electromagnetic waves from the sun that allows water to be present in the liquid state. 4B/H1*
Transfer of thermal energy between the atmosphere and the land or oceans produces temperature gradients in the atmosphere and the oceans. Regions at different temperatures rise or sink or mix, resulting in winds and ocean currents. These winds and ocean currents, which are also affected by the earth's rotation and the shape of the land, carry thermal energy from warm to cool areas. 4B/H2*
Climatic conditions result from latitude, altitude, and from the position of mountain ranges, oceans, and lakes. Dynamic processes such as cloud formation, ocean currents, and atmospheric circulation patterns influence climates as well. 4B/H5** (NSES)
8C/H4*
5D/H3
5D/H2*
The earth's climates have changed in the past, are currently changing, and are expected to change in the future, primarily due to changes in the amount of light reaching places on the earth and the composition of the atmosphere. The burning of fossil fuels in the last century has increased the amount of greenhouse gases in the atmosphere, which has contributed to earth's warming. 4B/H6** (SFAA)
5E/H3
Plants on land and under water alter the earth's atmosphere by removing carbon dioxide from it, using the carbon to make sugars and releasing oxygen. This process is responsible for the oxygen content of the air. 4C/H1*
Greenhouse gases in the atmosphere, such as carbon dioxide and water vapor, are transparent to much of the incoming sunlight but not to the infrared light from the warmed surface of the earth. When greenhouse gases increase, more thermal energy is trapped in the atmosphere, and the temperature of the earth increases the light energy radiated into space until it again equals the light energy absorbed from the sun. 4B/H4** (SFAA)
Because the earth turns daily on an axis that is tilted relative to the plane of the earth's yearly orbit around the sun, sunlight falls more intensely on different parts of the earth during the year. The difference in intensity of sunlight and the resulting warming of the earth's surface produces the seasonal variations in temperature. 4B/H3** (BSL)
Energy Transformations (p. 25)
In a fluid, regions that have different temperatures have different densities. The action of a gravitational force on regions of different densities causes them to rise or fall creating currents that contribute to the transfer of energy. 4E/H8** (BSL)
Flow of Matter in Ecosystems (v. 1, p. 77)
5E/M1b
4C/H1*
4B/E2
5D/H2*
4F/M8**
4D/M9**
The number of hours of daylight and the intensity of the sunlight both vary in a predictable pattern that depends on how far north or south of the equator the place is. This variation explains why temperatures vary over the course of the year and at different locations. 4B/M13**
Thermal energy carried by ocean currents has a strong influence on climates around the world. Areas near oceans tend to have more moderate temperatures than they would if they were farther inland but at the same latitude because water in the oceans can hold a large amount of thermal energy. 4B/M9*
The atmosphere is a mixture of nitrogen, oxygen, and trace amounts of water vapor, carbon dioxide, and other gases. 4B/M15** (NSES)
Climates have sometimes changed abruptly in the past as a result of volcanic eruptions or impacts of huge rocks from space. 4B/M6*
4C/M1
4A/M4
The temperature of a place on the earth's surface tends to rise and fall in a somewhat predictable pattern every day and over the course of a year. The pattern of temperature changes observed in a place tend to vary depending on how far north or south of the equator the place is, how near to oceans it is, and how high above sea level it is. 4B/M12**
Thermal energy is transferred through a material by the collisions of atoms within the material. Over time, the thermal energy tends to spread out through a material and from one material to another if they are in contact. Thermal energy can also be transferred by means of currents in air, water, or other fluids. In addition, some thermal energy in all materials is transformed into light energy and radiated into the environment by electromagnetic waves; that light energy can be transformed back into thermal energy when the electromagnetic waves strike another material. As a result, a material tends to cool down unless some other form of energy is converted to thermal energy in the material. 4E/M3*
Water evaporates from the surface of the earth, rises and cools, condenses into rain or snow, and falls again to the surface. The water falling on land collects in rivers and lakes, soil, and porous layers of rock, and much of it flows back into the ocean. The cycling of water in this way and the atmosphere is a major determiner of the weather patterns on earth. 4B/M7*
The earth has a variety of climates, defined by average temperature, precipitation, humidity, air pressure, and
Human activities, such as reducing the amount of forest cover, increasing the amount and variety of chemicals released into the atmosphere, and intensive farming, have changed the earth's land, oceans, and atmosphere. Some of these changes have decreased the capacity of the environment to support some life forms. 4C/M7
11C/E1*
11C/E2a*
11C/M6*
Light and other electromagnetic waves can warm objects. How much an object's temperature increases depends on how intense the light striking its surface is, how long the light shines on the object, and how much of the light is absorbed. 4E/M6**
4E/M3
4E/M2
4D/M3ab
4D/M3cd
4F/M8**
Energy can be transferred from one system to another (or from a system to its environment) in different ways: 1) thermally, when a warmer object is in contact with a cooler one; 2) mechanically, when two objects push or pull on each other over a dstance; 3) electrically, when an electrical source such as a battery or generator is connected in a complete circuit to an electrical device; or 4) by electromagnetic waves.
frozen), and the entire planet is surrounded by a relatively thin layer of air. 4B/M2ab*
Use of Earth's Resources (p. 23)
Interdependence of Life (p. 33)

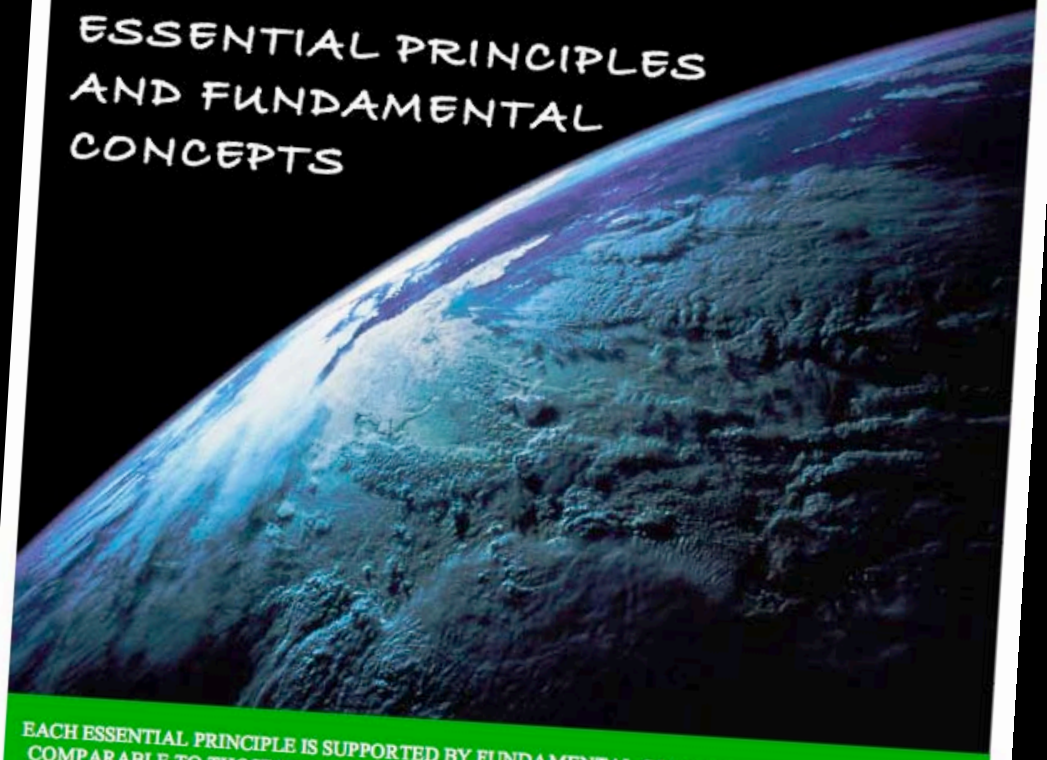
Framework for Climate & Weather Education Workshop Summary Report

April 11-13, 2007

A CLIMATE-ORIENTED APPROACH
TO TEACHING SCIENCE STANDARDS

CLIMATE LITERACY

ESSENTIAL PRINCIPLES AND FUNDAMENTAL CONCEPTS



EACH ESSENTIAL PRINCIPLE IS SUPPORTED BY FUNDAMENTAL CONCEPTS COMPARABLE TO THOSE UNDERLYING THE NATIONAL SCIENCE EDUCATION STANDARDS (NSES) AND AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE (AAAS) BENCHMARKS.

CONSULT THE **OVERVIEW MATRIX** (UNDER DEVELOPMENT) TO INTEGRATE CLIMATE LITERACY INTO YOUR CURRICULUM.

1 **Life on Earth has been shaped by, depends on, and affects climate.**

LIFE & CL[IMATE]

a. All or[ganisms] inclu[de] chan[ges] [and] weather extremes.

b. Chan[ges] very [large] changes in ecosystems. (Based on AAAS, 5D/H1)

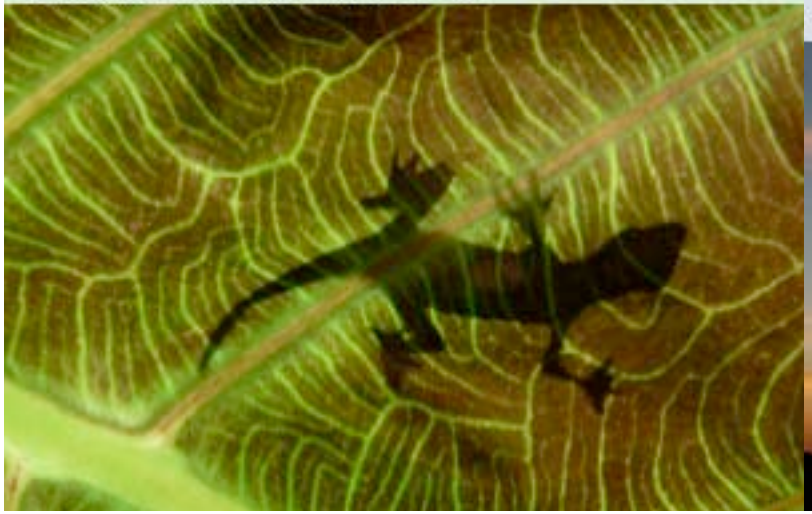
c. Changes in environmental conditions can affect the survival of individual organisms and entire species. (Based on AAAS, 5F/M2b)

d. Human societies have developed food, energy, transportation, and social systems that are dependent on climate and vulnerable to climate changes.

e. These human systems have developed during a relatively stable period in Earth's climate history.

f. Life o[n] and h[uman] subst[antially].

Source: Ryan Vachon, CIRES Outreach, (303) 735-3641



2 **We understand the climate system through observation and modeling.**

[Climate science operates under the assumption that Earth's climate system is understandable,] predictable enough to be worth investigating.

a. Fundamental characteristics of the climate system are understood well enough to support decision-making, even though research continues into many dynamics of climate change. (Based on AAAS, 12A/H3)

c. Data gathered through observations from weather stations, buoys, satellites, ice cores, tree rings, cave deposits, and other sources provide an understanding of past climates and climate changes.

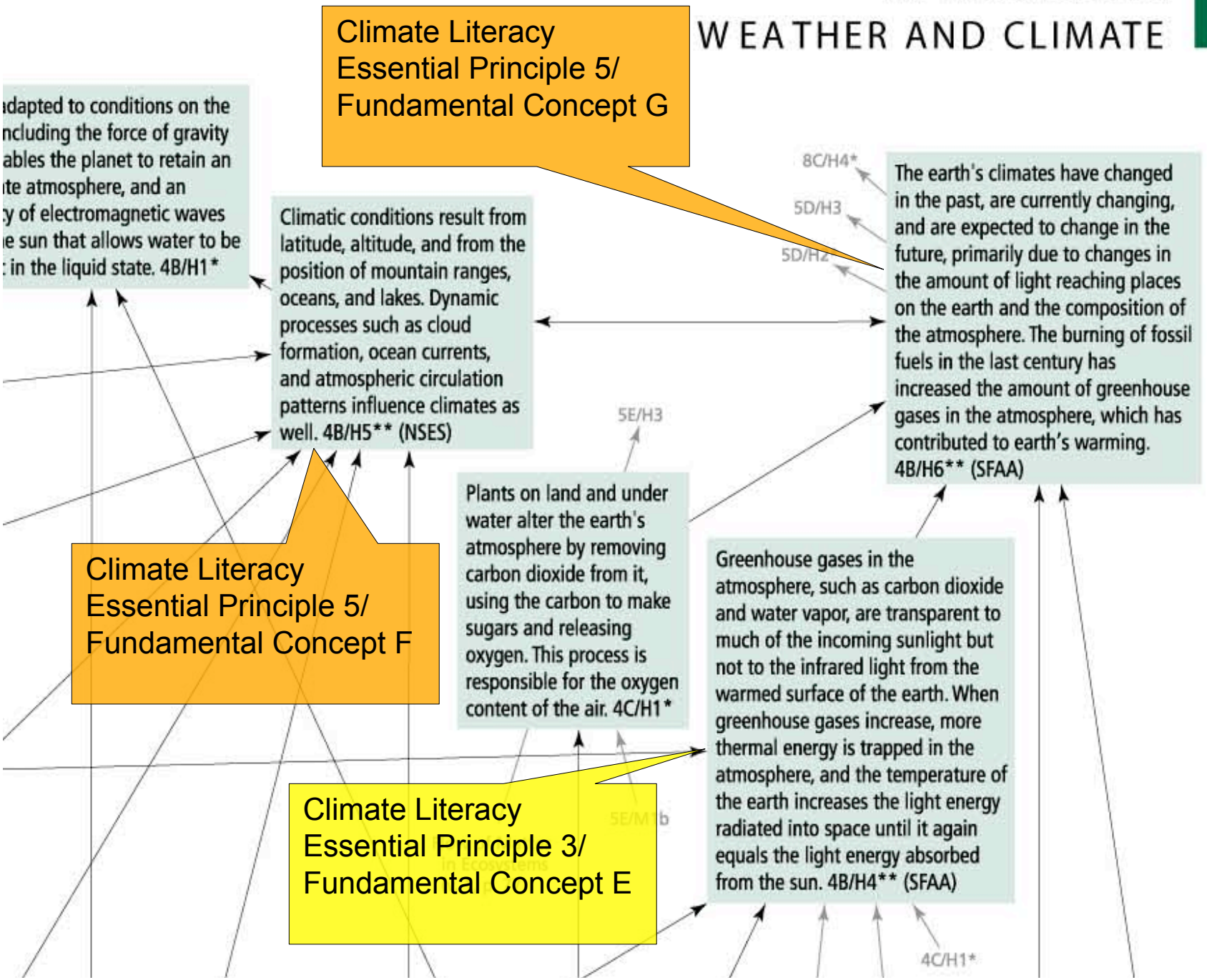
d. Using observations, logic, and experiments to construct and refine computer models and scientific explanations leads to better understanding of the climate system's behavior and more reliable projections of future climate changes. (Based on AAAS, 1B/H6)

Source: Forrest M. Mims III, Geronimo Creek Observatory, (830) 372-0548

No matter how well one theory fits observations, a new theory might fit them just as well or better, or might fit a wider range of observations. In science, the testing, revising, and occasional discarding of theories, new and old, never ends. This ongoing process leads to an increasingly better understanding of how things work in the world but not to absolute truth. Evidence for the value of this approach is given by the improving ability of scientists to offer reliable explanations and make accurate predictions. (AAAS, 1A/H3)

There is a danger of choosing only the data that show what is expected by the person doing the choosing. (AAAS, 9D/E5c)

WEATHER AND CLIMATE



3 The Sun is the primary source of Earth's energy

DRIVES EARTH SYSTEM

a. Solar energy heats the atmosphere and water through the global water cycle.

b. Daily variations of solar energy caused rotation drive many weather processes.

c. The tilt of Earth on its axis causes sunli more intensely on different parts of Ear year, resulting in seasonal changes (Bas 4B/H3)

d. Changes in Earth's orbit around the sun thousands of years alter the amount of received on Earth and impact long-term processes such as Ice Ages

e. Greenhouse gases in the atmosphere, s carbon dioxide and water vapor, trap int from the warmed surface of Earth, crea "Greenhouse Effect" which allows liquid exist on much of Earth's surface (Based H4)

f. Sunlight is the ultimate source of most we use. The energy in fossil fuels such coal comes from energy that organisms through photosynthesis from the sun lo (Based on AAAS 8C/H8)

4 Earth's weather and climate system are the result of complex interactions between land, ocean, ice and atmosphere.

COMPLEX INTERACTIONS

a. Solar energy drives Earth's clima

b. Earth's land, oceans, and atmos transfer heat (energy) differently dynamic climate system

c. Earth's atmosphere and ocean ar and impact climate in complex w

d. Water cycling is fundamental to

e. The water cycle is closely connec carbon cycle through biologic pro photosynthesis and decay, and c

f. Earth's atmosphere is the primar and climate factors such as temp air pressure, and wind.

g. Ocean circulation serves as a the Changes in the ocean's circulatio large, abrupt changes in climate

h. Relatively small amounts of gree as carbon dioxide, methane and as refrigerants can significantly r Greenhouse Effect.

i. Human beings are part of Earth's Human activities can, deliberatel alter the equilibrium of the clima on AAAS, 5D/H3)

5 Earth's weather and climate vary over time and place.

VARIABILITY & CHANGE

a. "Weather" is the state of the atmosphere at a particular place and time and is influenced by climate and many local factors.

b. "Climate" describes the prevailing or general weather conditions for an area, or for the entire planet.

c. Cycles, such as the seasons or weather extremes, can be described by what there cycle length or frequency is, what their highest and lowest values are, and when these values occur. Different cycles range from many years down to a fraction of a second. (Based on AAAS, 11C/M6*)

d. The temperature of a place on Earth's surface tends to rise and fall in a somewhat predictable pattern every day and over the course of a year. (AAAS 4B/M12)

e. Differences in the intensity of sunlight warming Earth's surface produce the daily, seasonal and very long-term variations in temperature. (Based on AAAS, 4B/H3b)

f. Earth's changing climate states are defined by the average temperature, precipitation, humidity, air pressure, and wind, over long timescales. (Based on AAAS, 4B/H5a)

g. Earth's climate has changed in the past, is currently changing, and is expected to change in the future. (Based on AAAS 4B/M14)

h. Natural processes that drive Earth's long-term

6 Recent climate change is primarily caused by human activities.

HUMAN ACTIVITIES

a. Human beings are a significant part of Earth's climate system.

b. Human activities, such as burning fossil fuels and increasing the amount and variety of chemicals released into the atmosphere, reducing the amount of forest cover, and rapidly expanding farming and industrial growth have changed Earth's land, oceans, and atmosphere and altered Earth's climate. (AAAS, 4C/M7a)

c. Some changes resulting from human activities have decreased the capacity of the environment to support various species. (Based on AAAS, 4C/M7b)

d. The observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in human-induced greenhouse gas concentrations, primarily from fossil fuel combustion and deforestation. (Based on IPCC, 2007)

Source: Ryan Vachon, CIRES Outreach, (303) 735-3641

7 Earth's climate system is influenced by human decisions, which are complex and involve economic costs and social values.

Source: Scott Bauer

MAKING DECISIONS

a. Decisions about the future involve weighing scientific evidence with uncertainties about future economic growth and energy use, costs and opportunities, moral values, and cultural norms.

b. Informed decision making is more effective when key assumptions and the basic facts are clearly identified and understood.

c. Population growth and industrialization increase demands for energy, potentially improving quality of life but also affecting climate worldwide. (Based on AAAS, 7G/M5)

d. The atmosphere is global, and decisions about energy use made in one region affect people and other species worldwide.

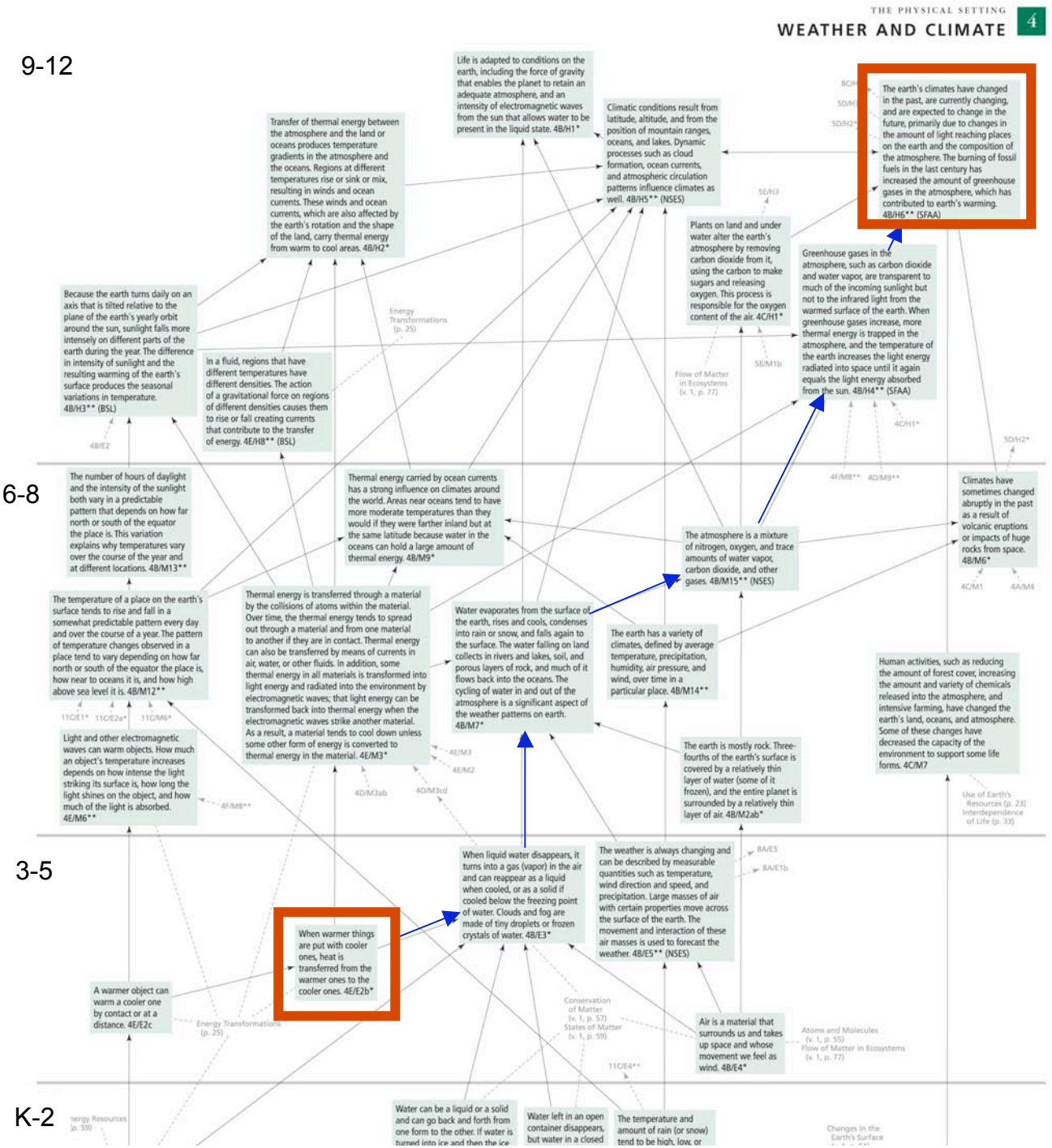
e. The decisions of one generation both provide and limit the range of possibilities open to the next generation. (Based on AAAS, 7C/H3)

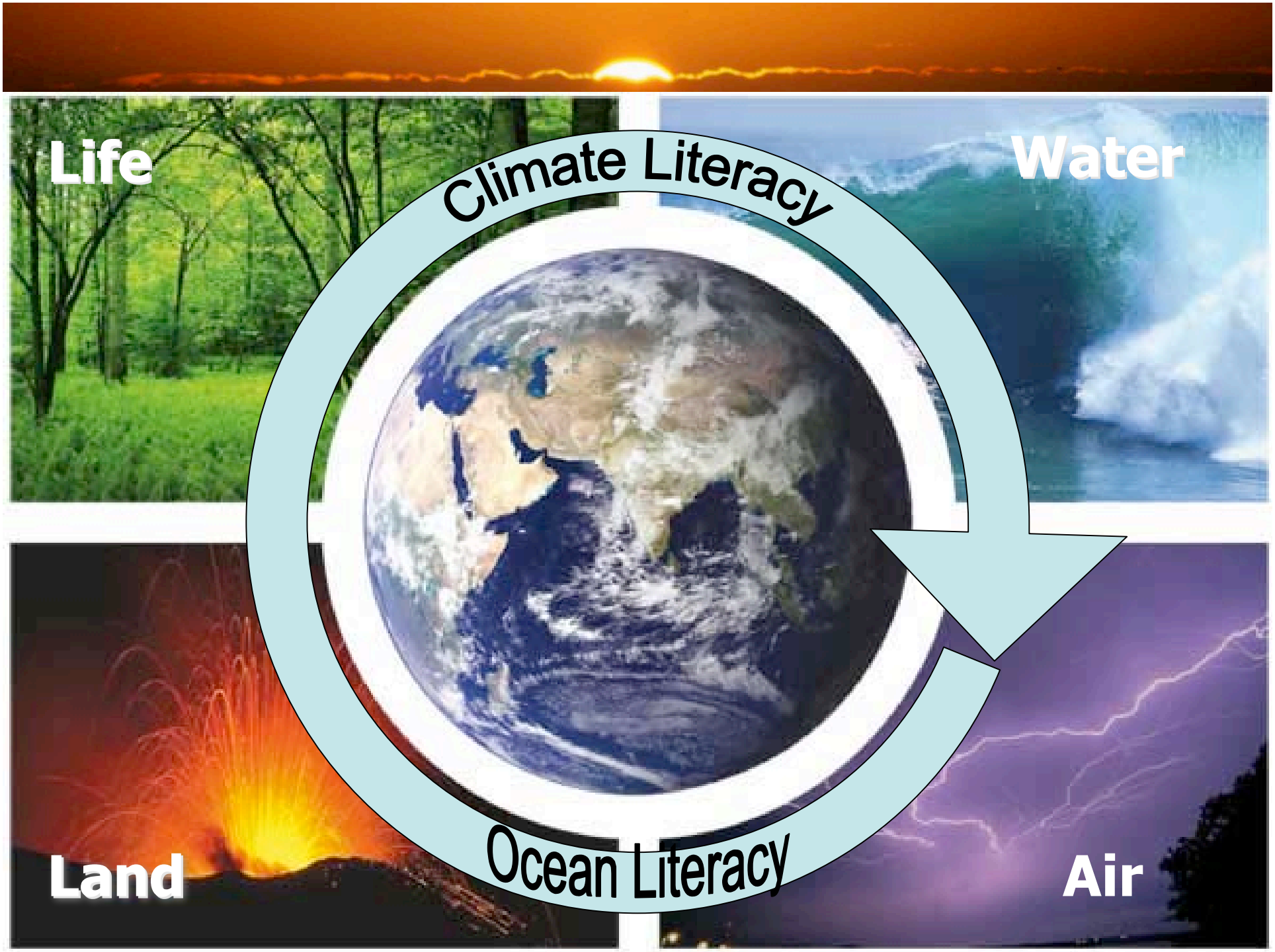
f. Decisions about energy use and adapting to climate change are made at all levels, from the individual to the global. (Based on AAAS, 8C/H5)

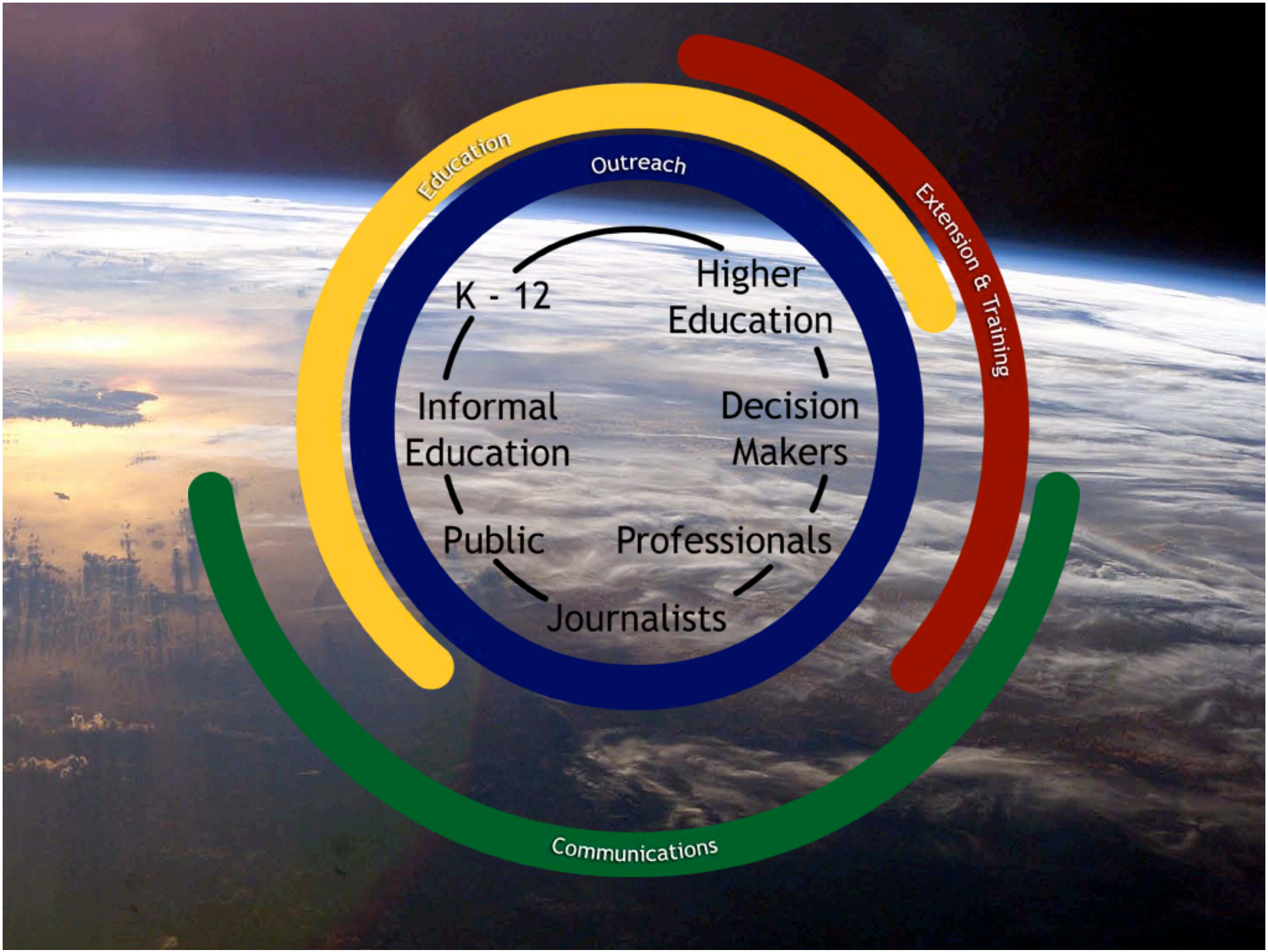
g. Societal change is triggered at the individual and community levels, and by leadership of industry

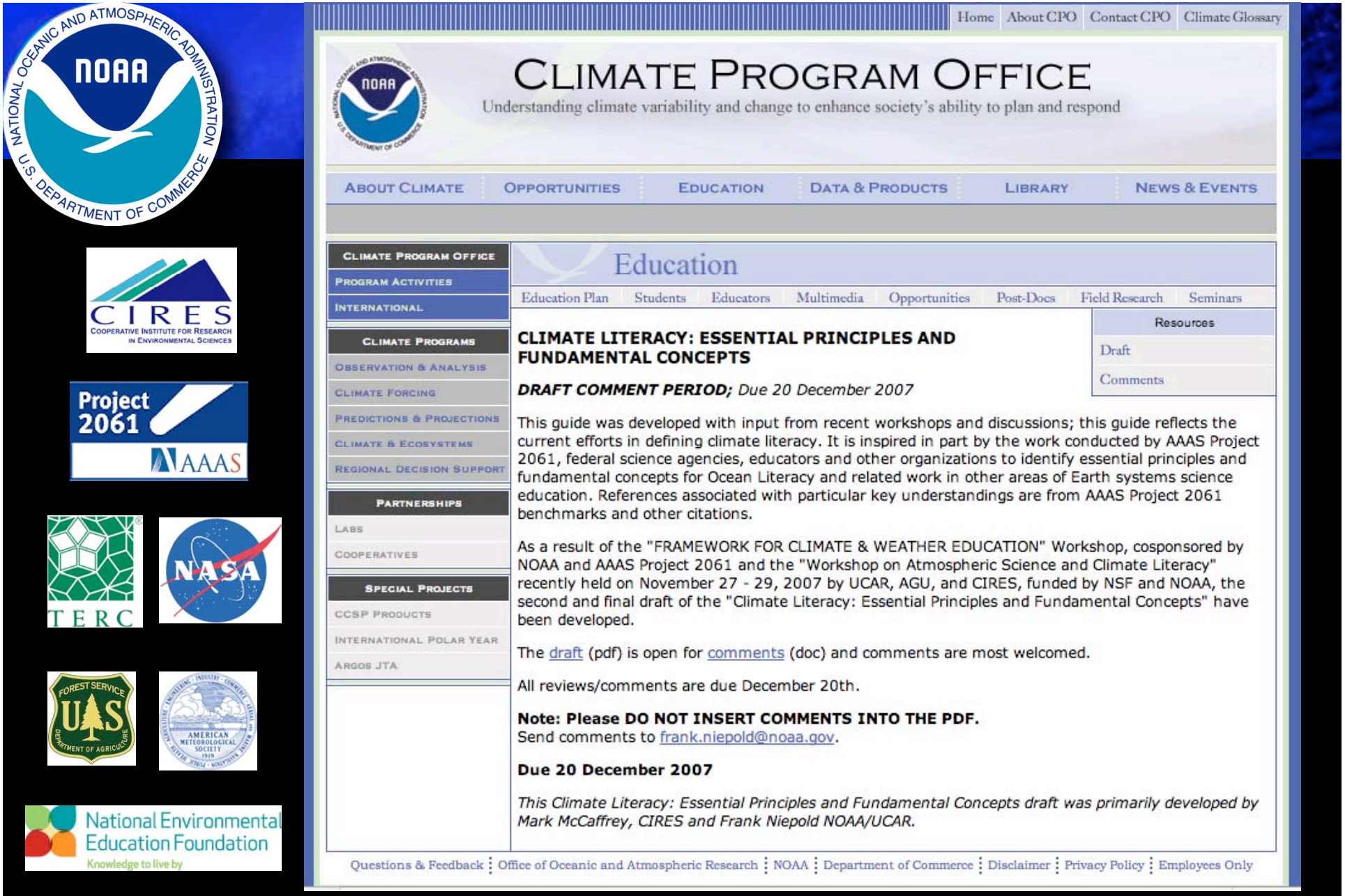
The earth's climates have changed in the past, are currently changing, and are expected to change in the future, primarily due to changes in the amount of light reaching places on the earth and the composition of the atmosphere. The burning of fossil fuels in the last century has increased the amount of greenhouse gases in the atmosphere, which has contributed to earth's warming. 4B/H6** (SFAA)

When warmer things are put with cooler ones, heat is transferred from the warmer ones to the cooler ones. 4E/E2b*

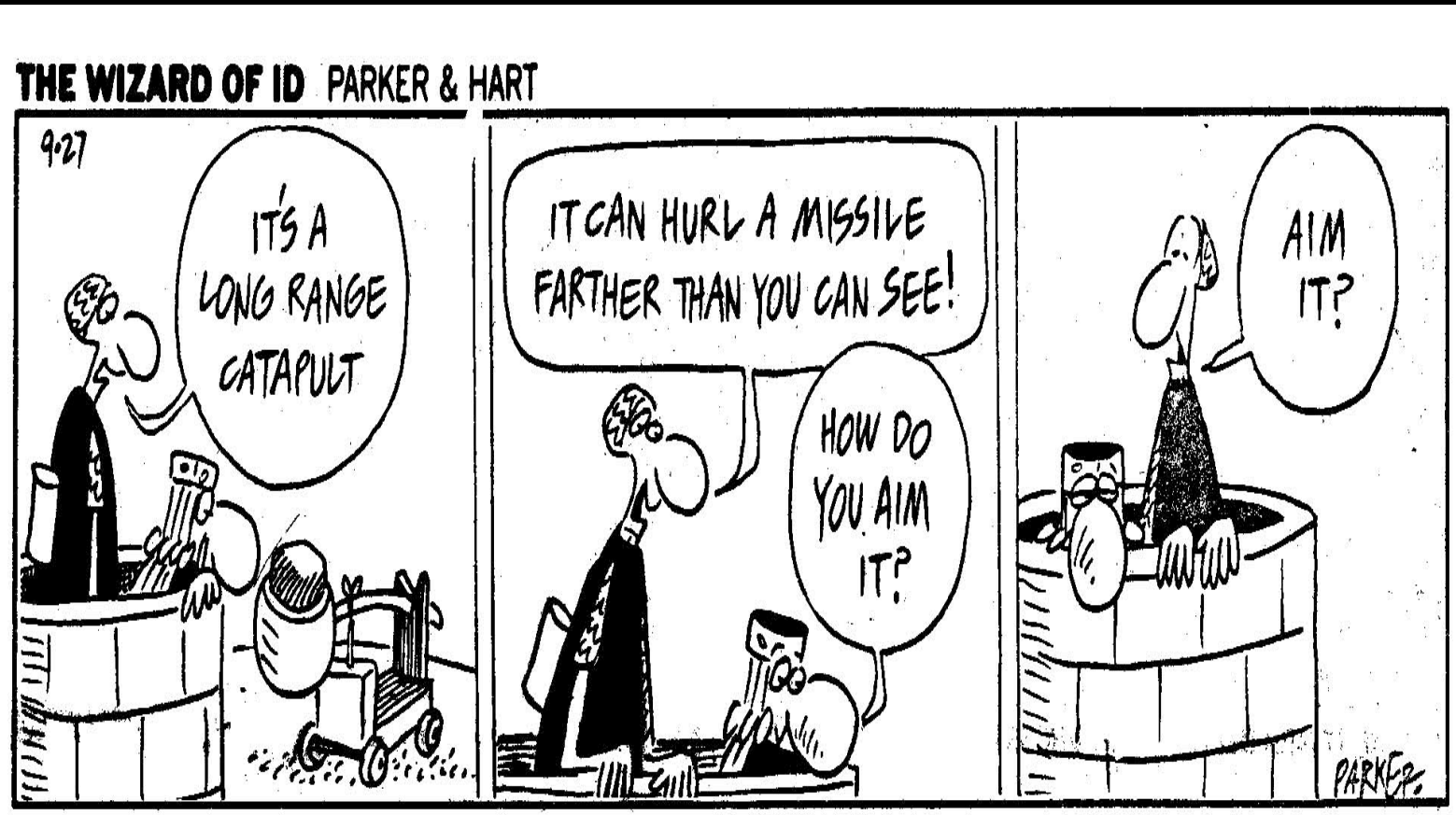



Life
Water
Climate Literacy
Land
Ocean Literacy
Air


Education
Outreach
Extension & Training
K - 12
Higher Education
Informal Education
Decision Makers
Public
Professionals
Journalists
Communications



http://www.climate.noaa.gov/education/


THE WIZARD OF ID PARKER & HART
9-27
IT'S A LONG RANGE CATAPULT
IT CAN HURL A MISSILE FARTHER THAN YOU CAN SEE!
HOW DO YOU AIM IT?
AIM IT?
PARKER