History of the Development of the Climate Literacy Essential Principles

Frank Niepold
National Oceanic and Atmospheric Administration
Climate Program Office,
Washington, D.C., USA

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

How well do US college graduates understand important science ideas?

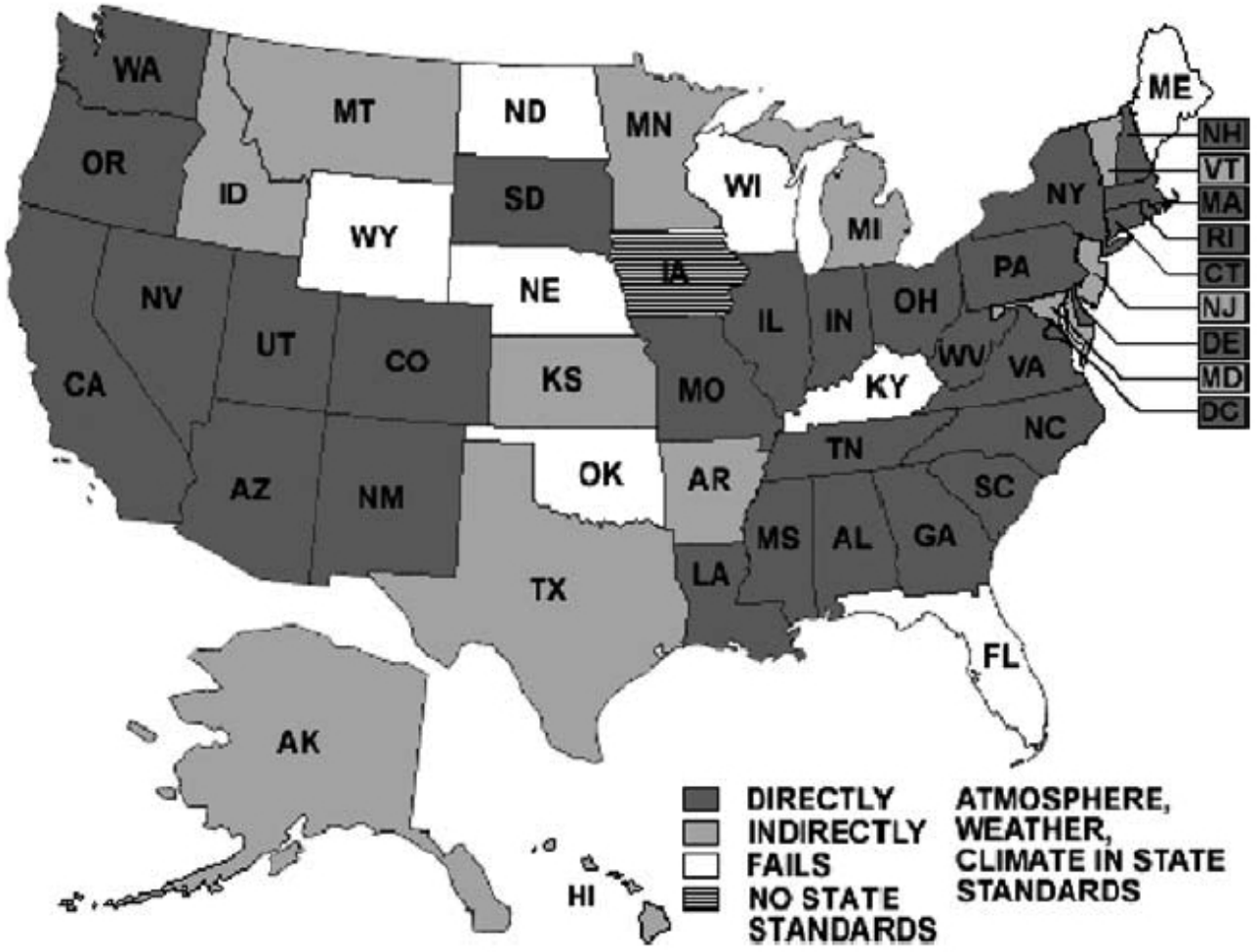
1. A seed grows into a large tree. Where did the mass of the tree come from?

1. What if I told you that the mass comes mainly from the carbon dioxide in the air?

Atmosphere, Weather and Climate Education in the U.S.

United States Global Change Research Program

National Grade - C+ (2.9)



Revolutionizing Earth System Science Education for the 21st Century Report, 2007 (page 34)

Critical Need for Climate Change Education and Communication

United States Global Change Research Program

Despite growing scientific evidence that global warming will have serious impacts worldwide, public opinion is moving in the opposite direction. Over the past year the United States has experienced rising unemployment, public frustration with Washington and a divisive health care debate, largely pushing climate change out of the news. Meanwhile, a set of emails stolen from climate scientists and used by critics to allege scientific misconduct may have contributed to an erosion of public trust in climate science.

It is also clear that public understanding of climate change fundamentals - that it is happening, is human caused, and will have serious consequences for human societies and natural ecosystems here in the United States and around the world - is heading in the wrong direction. These findings underscore the critical need for more and improved climate change education and communication.

Yale University and George Mason University, 2010

Effective Communications about Global Warming

United States Global Change Research Program

- Existence
- Attitudes
- Certainty
- Human Responsibility
- People's Ability To Remedy It

JON A. KROSNICK, ALLYSON L. HOLBROOK, LAURA LOWE and PENNY S. VISSER, 2006, Stanford

United States Global Change Research Program

Defining Climate Literacy

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.

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*

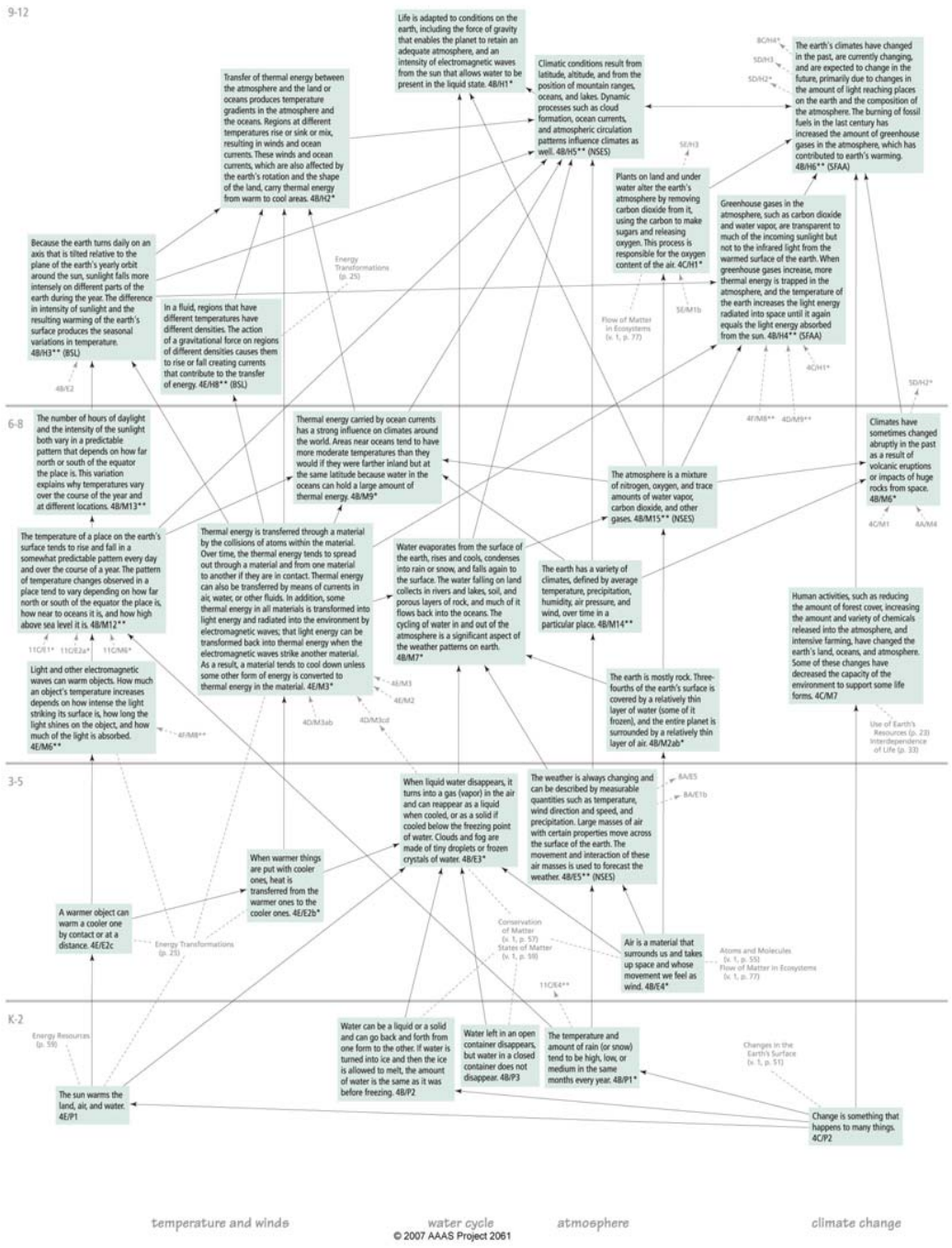
Students of all ages (including college students and adults) have difficulty understanding what causes the seasons. Students may not be able to understand explanations of the seasons before they reasonably understand the relative size, motion, and distance of the sun and the earth (Sadler, 1987; Vosniadou, 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; Salierno, 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.



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)

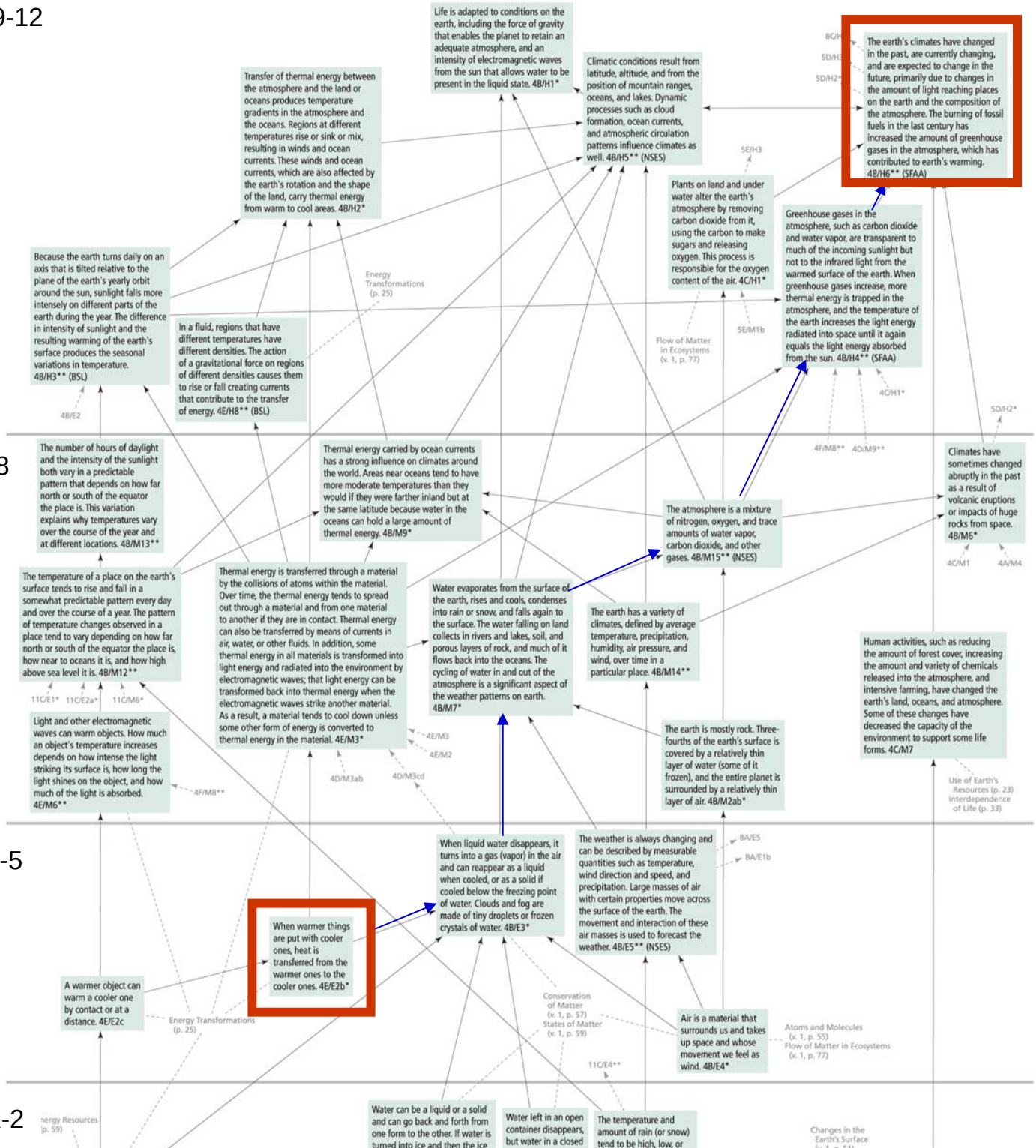
When warmer things are put with cooler ones, heat is transferred from the warmer ones to the cooler ones. 4E/E2b*

9-12

6-8

3-5

K-2



Communicating and Learning About Global Climate Change

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

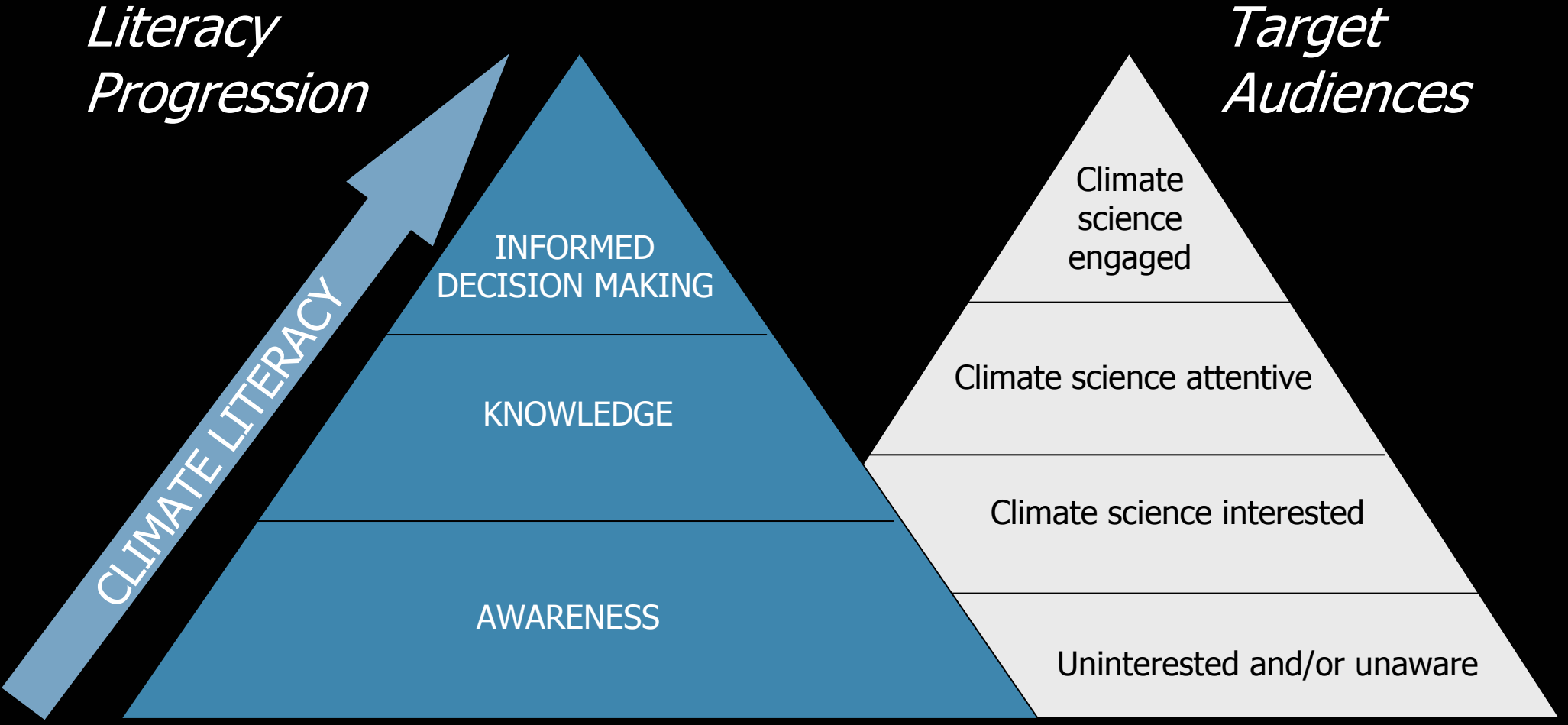
©Lonnie Thompson/Ohio State University

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…

Climate Literacy is…□

…a continuum of competency and is an ongoing process.



Climate Science Literacy is… □

…an understanding of your influence on climate and climate's influence on you and society.

A climate literate person:

- *understands* the essential principles of Earth's climate system,
- knows how to *assess* scientifically credible information about climate,
- *communicates* about climate and climate change in a *meaningful* way, and
- is able to make *informed* and *responsible* decisions with regard to actions that may affect climate.

ABOUT THIS GUIDE

Climate Literacy: The Essential Principles of Climate Science presents information that is deemed important for individuals and communities to know and understand about Earth's climate, impacts of climate change, and approaches to adaptation or mitigation. Principles in the guide can serve as discussion starters or launching points for scientific inquiry. The guide aims to promote greater *climate science literacy* by providing this educational framework of principles and concepts. The guide can also serve educators who teach climate science as a way to meet content standards in their science curricula.

Development of the guide began at a workshop sponsored by the National Oceanic and Atmospheric Administration (NOAA) and the American Association for the Advancement of Science (AAAS). Multiple science agencies, non-governmental organizations, and numerous individuals also contributed through extensive review and comment periods. Discussion at the National Science Foundation- and NOAA-sponsored Atmospheric Sciences and Climate Literacy workshop contributed substantially to the refinement of the document.

To download this guide and related documents, visit www.climatescience.gov.

U.S. Global Change Research Program /
Climate Change Science Program
1717 Pennsylvania Avenue, NW Suire 250 Washington DC 20006 USA
+1.202.223.6262 (Voice) + 1.202.223.3065 (Fax)
http://www.climatescience.gov
climate.literacy@climatescience.gov

Current Science and Educational Partners:

Advancing climate literacy

United States Global Change Research Program

Use the *"Climate Literacy: The Essential Principles of Climate Science"* (Version 2, March 2009) framework to organize resource development.

Establish a voluntary national climate education curriculum for K-16.

Continue investments in climate education research that lead to more effective strategies.

Provide a focus within individual agency programs on professional development for formal educators.

Support creation of interpretive and educational programs and products that leverage existing outreach and extension networks and informal science education venues.

Develop new resources and tools that utilize "new media" and emerging outlets for widespread dissemination and public engagement in climate.

Foster development of an agency-wide protocol for designating and labeling educational programs of merit (Climate education collections)

Establish mechanisms for monitoring public understanding of climate literacy, and related actions.

Coordinating Federal Investments in Climate and Earth System Science Education
-- Developed from ongoing discussions within the USGCRP Education Interagency Working Group

Climate Change Brings Opportunities

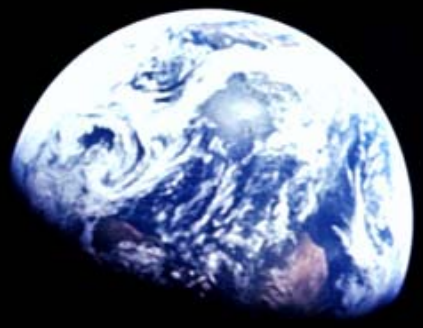
The security and stability of each nation and all peoples -- our prosperity, our health, and our safety -- are in jeopardy. And **the time we have to reverse this tide is running out.**

And yet, we can reverse it. John F. Kennedy once observed that "Our problems are man-made, therefore they may be solved by man." It is true that for too many years, **mankind has been slow to respond or even recognize the magnitude of the climate threat.** It is true of my own country, as well. We recognize that.

But this is a new day**. It is a new era.** And I am proud to say that the United States has done more to promote clean energy and reduce carbon pollution in the last eight months than at any other time in our history.

—President Barack Obama

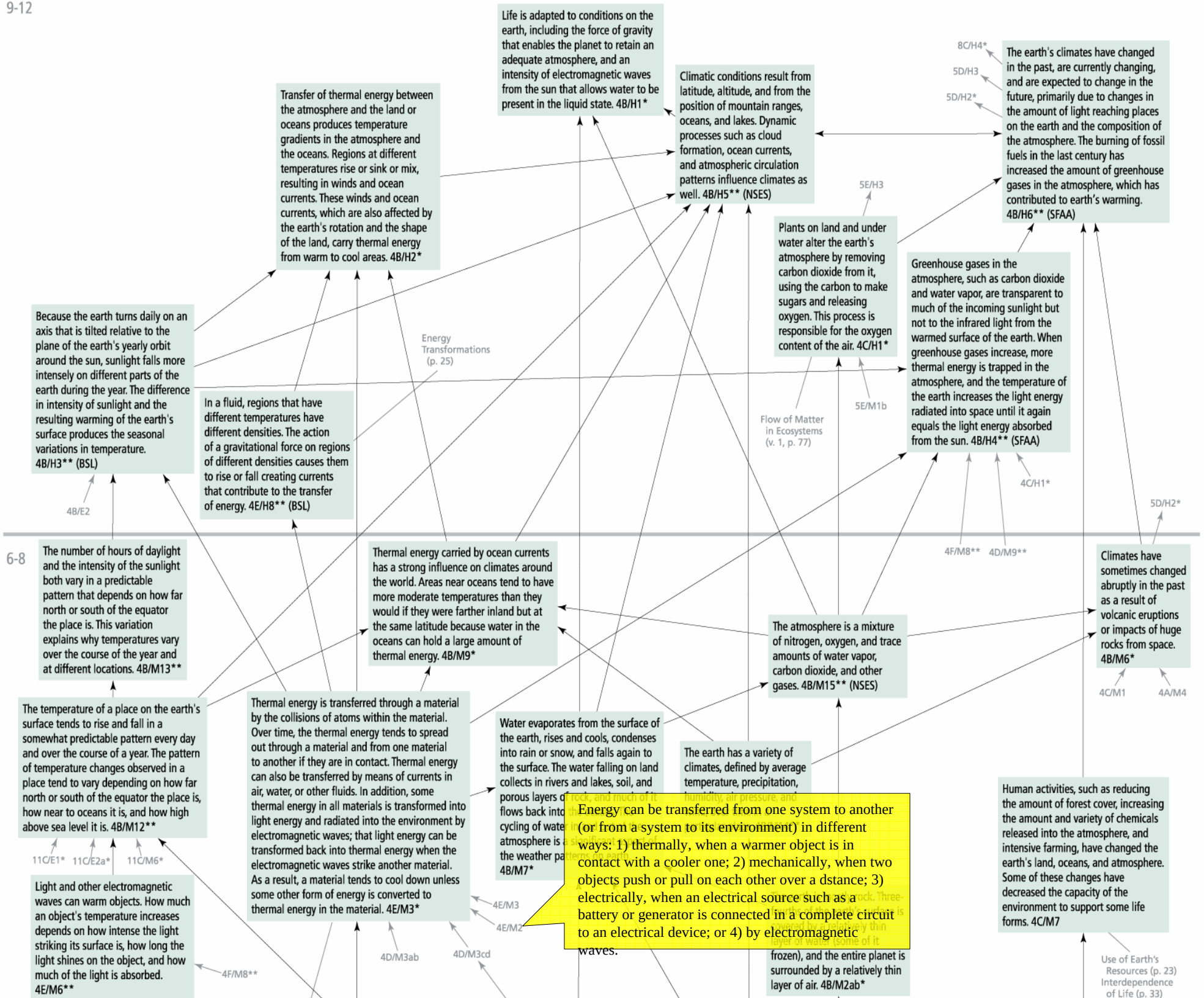
UN Summit on Climate Change, September 2009



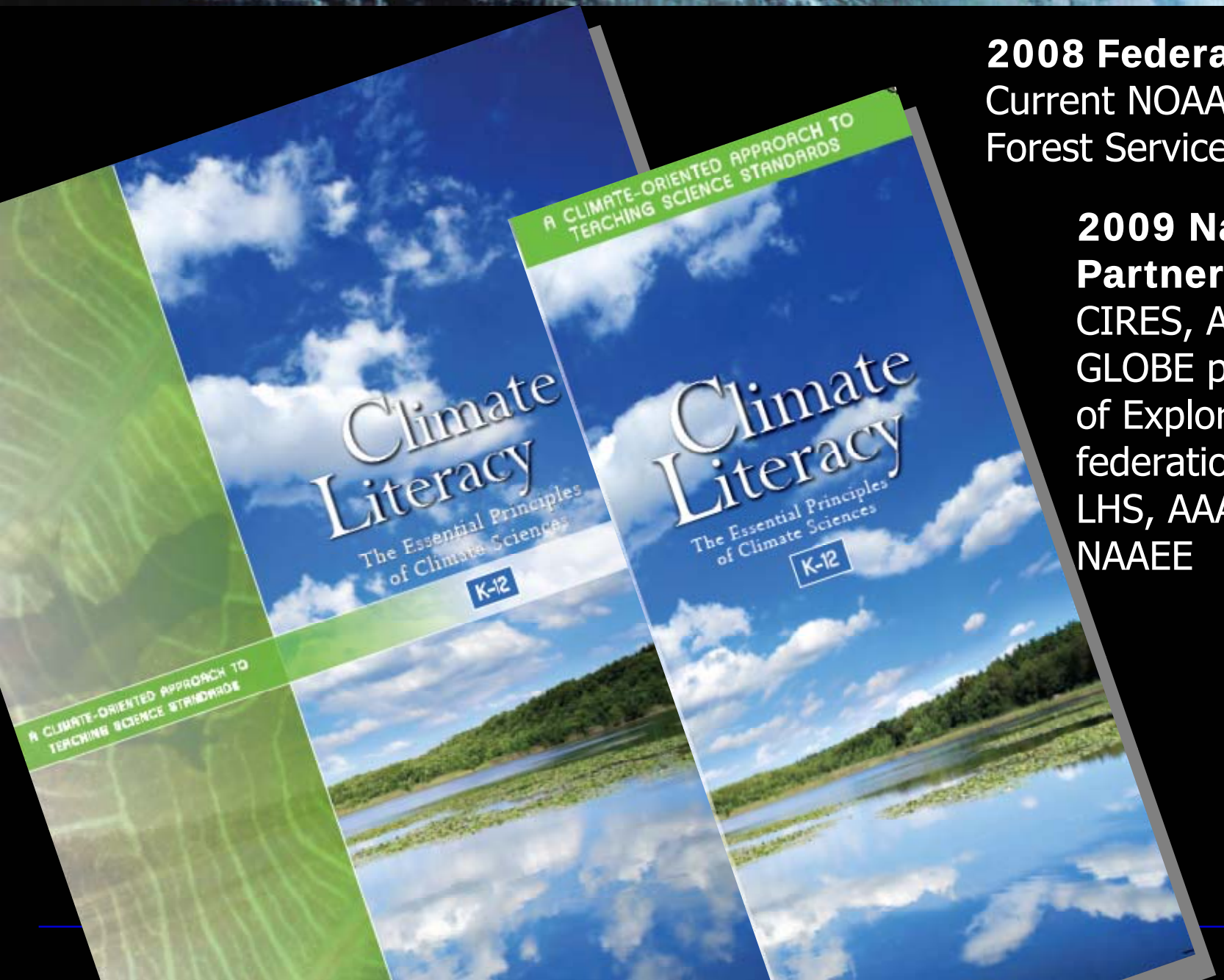
Frank Niepold
National Oceanic and Atmospheric Administration
Climate Program Office (UCAR),
Washington, D.C., USA
frank.niepold@noaa.gov

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


Back up slides


9-12
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*
6-8
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*
4F/M8**
4D/M9**
Climates have sometimes changed abruptly in the past as a result of volcanic eruptions or impacts of huge rocks from space. 4B/M6*
The atmosphere is a mixture of nitrogen, oxygen, and trace amounts of water vapor, carbon dioxide, and other gases. 4B/M15** (NSES)
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 the atmosphere is a major factor in the weather patterns on earth. 4B/M7*
The earth has a variety of climates, defined by average temperature, precipitation, humidity, air pressure, and
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*
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
Use of Earth's Resources (p. 23)
Interdependence of Life (p. 33)

United States Global Change Research Program



2008 Federal Partners. Current NOAA, EPA and US Forest Service

2009 National Partners. UCAR, NCAR, CIRES, AMS, TERC, GLOBE program, College of Exploration, ESIP federation, ASTC IGLO, LHS, AAAS Project 2061, NAAEE

United States Global Change Research Program

2 WE INCREASE OUR UNDERSTANDING OF THE CLIMATE SYSTEM THROUGH OBSERVATION AND MODELING

Mauna Loa Observatory at sunset, 2007

Source: *Forrest Mims III*

A. Climate science is based on the assumption that Earth's climate system is understandable and, therefore, that many

decades into the future is not constrained by the limitations meteorologists face in forecasting weather on much shorter timescales (days to weeks into the future).[1]

C. We gain understanding of climate and how it has changed over time from observational data from weather stations, buoys, satellites, radars, ice and ocean sediment cores, tree rings, cave deposits, native knowledge, and other sources.

D. Observations, experiments, and theory used to construct and refine computer models and develop scientific explanations

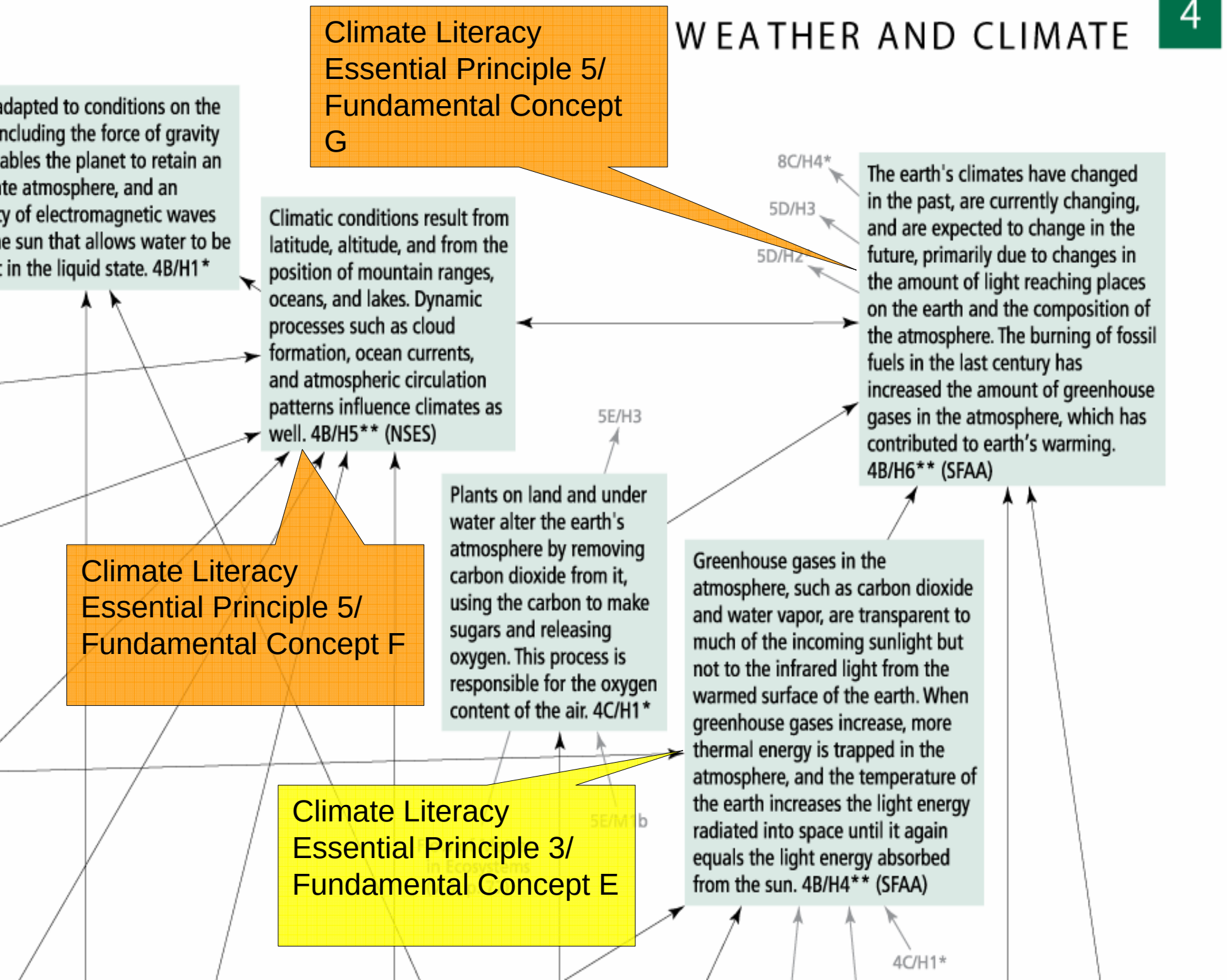
atmosphere-ocean system and how it relates to the overall climate system's behavior. As a result, more reliable projections of future climate changes will develop over time.

E. Fundamental characteristics of the climate system have been researched and are understood well enough to make reasonably accurate predictions about the climate system and, therefore, to support decision making, even though research continues into many aspects of climate change.

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



CLIMATE LITERACY: The Essential Principles of Climate Science

Each Essential Principle is supported by Fundamental Concepts comparable to those underlying the National Science Education Standards (NSES) and the American Association for the Advancement of Science (AAAS) Benchmarks for Science Literacy.

Guiding Principle. Humans can take actions to reduce climate change and its impacts

1. The Sun is the primary source of energy for Earth's climate system

2. Climate is regulated by complex interactions among components of the Earth system.

3. Life on Earth depends on, is shaped by, and affects climate

4. Climate varies over space and time through both natural and man-made processes

5. Our understanding of the climate system is improved through observations, theoretical studies, and modeling

6. Human activities are impacting the climate system

7. Climate change will have consequences for the Earth system and human lives