

WEATHER, CLIMATE AND CLIMATE CHANGE



CANADIAN SUSTAINABILITY CURRICULUM REVIEW INITIATIVE

Theme: Weather, Climate and Climate Change

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Background

Weather, Climate, and Climate Change is one of twelve themes that have been prepared to contribute to the review of curriculum policy in Canada. The project supports the United Nation's Decade of Education for Sustainable Development call to review current policies and procedures to ensure that students are prepared to meet the current and future challenges we all face. A full project description is available on the Learning for a Sustainable Future website www.lsf-lst.ca

Theme documents follow a template designed for this project. An explanation for the layout and content of the project is found on the LSF website under Curriculum Policy Review.

Revisions of this document occur as new insights, research and learning programs come to light. Comments and contributions to this ongoing process and application and testing of the ideas presented here are encouraged.

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CONTEXT AND DESCRIPTION OF WEATHER, CLIMATE AND CLIMATE CHANGE

The vast majority of the world's scientific community acknowledges climate change as a problem of global proportions whose solution may collectively be our greatest challenge.¹ Despite this unprecedented recognition, climate change is grossly underrepresented in curriculum policy in most Canadian jurisdictions.

The scope and complexity of the problem presents educators with a formidable challenge. Its understanding involves phenomena that cross traditional school subject boundaries ranging from geosciences to media and requires that one have a grasp of the process of change and an understanding of system dynamics. Successful learning about climate change requires an interdisciplinary approach on a scale that spans the personal to the international.

How society is presently responding to the climate change phenomena can either be viewed as a serious complicating factor or an ideal context in which to learn about it. Climate change is another example of how various groups respond to scientific findings that challenge broadly held societal ambitions. It is under these circumstances that students bring to their formal learning, their understanding about climate change gained through the media whose reporting of scientific findings are tempered by their level of scientific literacy and other societal views.²

It is important to acknowledge through learning that although climate prediction has a significant element of uncertainty. The understating of how the climate system functions is sufficiently understood to account for many of the climate changes that have occurred in the past and predict those that may occur in the future.³ Despite the ambiguity of the science, the scientific community overwhelmingly accepts the link between current climate changes continuing into the future as a result of human activity on the planet.

The Sustainability Curriculum Review Project addresses a number of themes that have an important part in understating climate change (energy and its use, ecosystems, water). This document addresses climate change in the context of learning about weather and climate, two areas that have received attention in traditional curriculum policy in the past. This provides curriculum developers a good starting point to addressing climate change in policy but it also provides the best context for students to learn about the climate change challenge. We cannot expect students to understand climate change without a sound understanding of the dynamics of weather and climate and the influence these have on all aspects of human and ecological functioning.

Understanding climate change requires that curriculum policy expand traditional carbon cycle instruction to include the role of carbon in environmental systems. This has been advocated as a means of bringing consistency to science through a focus on big ideas and as being necessary for the environmental decision making of citizens as our technological capacity expands. Understanding the system processes that capture and release carbon is important in understanding how human activity has resulted in a net flow of carbon from forests and fossil fuels to the atmosphere.⁴

A significant number of governments and corporations at the national and international levels have initiated actions to address climate change. Including climate change in curriculum policy is important to these efforts since the participation of citizens in climate change remediation actions is enhanced when participants are well informed about global climate.⁵

WEATHER, CLIMATE, AND CLIMATE CHANGE –ORGANIZING STRANDS

This document organizes learning across four grade groups (1 to 3, 4 to 6, 7 to 9 and 10 to 12) based on the following strands.

1. Weather and Climate

- Learning elements are found for this strand in all grade groups.
- It includes learning elements that lead to understanding the definition and functioning of weather and climate.
- Included through out the strand is the application of ‘ways of thinking’ including systems, cycles, change, scale, and complexity.

2. Influence of Weather and Climate

- Learning elements are found for this strand in all grade groups.
- This strand addresses normal weather and climate and their impact on ecosystems, economics and other people –ecosystem interactions. The intent is to have students understand the profound impact that weather and climate have on all aspects of ecosystem components including people. An understanding of this influence provides students with a context for understanding the implications and scope of human induced climate change.

3. Human Impact on Climate

- Learning elements for this strand start at the grade 7 to 9 grouping in accordance to what the literature deems as developmentally appropriate for these students.
- The focus of this strand is an understanding of how human activity has influenced climate from the past to the present, as well as the scientific predictions for the future.

4. Climate Change Impact

- Learning elements for this strand start at the grade 7 to 9 grouping in accordance to what the literature deems as appropriate for these students.
- The focus of this strand is the impact of human induced climate change, at present and in the future on ecosystems and human activity (including environmental health, economic and social elements).

5. The Response to Climate Change -social and technical

- Learning elements for this strand start at the grade 7 to 9 grouping in accordance to what the literature deems as appropriate for these students.
- The reaction to climate change varies considerably by sector which determines in part how the science of climate change is received.
- The nature of actions that can be taken differs considerably from the individual/family through to international levels.
- Responses can vary from social- economic to technical ones.
- Misinforming others plays a role in how climate change is addressed.
- As climate change is already underway, adapting to the results should be considered.

NOTES FOR CURRICULUM DESIGNERS

Weather, climate, and climate change require understanding of learning from the traditional subjects of science and geography. Instruction often does not take an interdisciplinary approach and hence ends up being less than optimal. Curriculum developers are in the best position to address this challenge by expanding the scope of curriculum policy in either subject area to promote interdisciplinary learning. A thematic approach, taking system NTS (Nature, Technology and Society) into consideration is more appropriate for understanding the urgent problems of today, such as the enhancement of the greenhouse effect.⁶

The complexity of the climate change issue with regard to the role of the carbon cycle can be addressed by moving to understanding based on models or patterns of processes in systems. Most people use a narrative mindset in terms of events caused by actors in settings to approach understanding of complex issues, however large issues such as climate change cannot be fully understood using this approach. Citizen understanding of the carbon cycle requires the conceptual tools and practices that will enable them to see important connections between environmental issues, their individual actions and understanding modern environmental policy debates.⁷

As students mature, a number of age-related issues need to be considered for each grade group:

Grades 10 to 12

- It is now appropriate to bring the full complexity of the climate change issue to students including the range of responses occurring in society.
- The scale of the issue should expand to address global implications and its long-term intergenerational nature.⁸
- Investigation can include analysis of the influence of individuals and groups and possible actions.⁹
- These learners can understand how different political and economic systems account for, manage, and affect natural resources and environmental quality¹⁰
- Investigation can consider the nature of the response and the success of the response of public means of addressing change and conflict.¹¹ Examining climate change as an example of the “tragedy of the commons” can provide insight as to effective and ineffective responses.
- These students can now address and integrate major natural processes (carbon cycle, water cycle) relevant to climate change and can relate these processes, especially those that are large-scale and long-term, to characteristics of the Earth¹². They can differentiate and decide which processes and systems are connected to climate change with increased accuracy.¹³

Grades 7 to 9

- The system nature of climate is introduced here. To understand climate change, associated phenomena like the greenhouse effect, the nature of the atmosphere, the range of solar radiation and their varying characteristics are all required.
- These students need to have a basic understanding of most of the physical processes that shape the Earth.¹⁴

Grades 4 to 6

- Instruction for these students focuses on achieving a basic understating of how weather and climate work and the dependence of plants, animals and people on them.¹⁵
- There is no basis justifying human induced climate change instruction for this grade group.
- These students can keep journals, use instruments, and record their observations and measurements as a mean of studying local weather and climate.¹⁶

Grades 1 to 3

- No instruction about climate change is supported at this level.
- Since these students are eager to find out how things work in the natural world, instruction should encourage the asking of many questions and the use of observation and recording of readily observable phenomena. Short and long term changes such as daily weather and seasonal patterns respectively are an excellent context to apply these insights about these learners.¹⁷
- Restrict instruction to phenomena that are visible in the local environment over relatively short time periods (the school day, the school term, the school year). In learning about seasons, students need direct experience with light and surfaces-shadows, reflection, and warming effects of sunlight at different angles. The impact of seasonal change and therefore weather changes on the activities of living things and human activity should be a focus.¹⁸



Grade Grouping: Grades 10 to 12

Exemplary Learning Programs	Developmental Readiness and Major Misconceptions
<p>Global Eye on Climate Change Students use this website to explore the issue of Global Warming from a variety of perspectives including economic, social and environmental. Students are given specific information about Indonesia and the impact Climate Change has on this area of the world. This website is interactive, includes pictures and encourages self-directed inquiry learning.</p> <p>Main Instructional Methods Employed:</p> <ul style="list-style-type: none"> • Self-directed Learning • Audience Beyond the Classroom • Integrated Learning • Issue relevant to the world beyond the school • Cooperative learning • Case Studies <p>http://www.globaleye.org.uk/secondary_spring05/focuson/index.html - viewed May3/06</p> <p>Climate Change- Fact or Fiction? Information Analysis Skills for Senior Secondary School Students Instruction in information analysis skills and identification of propaganda techniques precedes student viewing and analysis of climate change websites from the range of societal perspectives on the topic. Through this learning experience students can better make judgments as to the trustworthiness of online sources.</p> <p>Main Instructional Methods Employed:</p> <ul style="list-style-type: none"> • Analysis of propaganda techniques • Guided discussion • Consideration of alternatives • Project based learning –optional <p>http://lsf-lst.ca/media/ClimateChangeFactorFiction.pdf</p>	<p>Developmental Readiness</p> <ul style="list-style-type: none"> • These students can understand Canada’s international role within the climate change debate and gain insight into the international decision making that is needed to address the issue. <p>Misconceptions</p> <ul style="list-style-type: none"> • Students still confuse the causes, impact, and solution to major environmental problems such as ozone layer depletion and global warming/climate change.¹⁹ • Many hold the misconception that changes in today’s climate are a result of present day greenhouse gas emissions. Scientists attribute current climate change to human activity from the past while today’s greenhouse gas emissions will impact future generations.²⁰ • A profound lack of understanding of the causes and dynamics of climate change are revealed by studies that show that some believe using unleaded gasoline and reducing the use of pesticides would help to reduce global warming, or that reducing the use of nuclear power to generate electricity would reduce global warming.²¹ • Many students at this age acknowledge that drastic CO₂ limitations in industrialized and developing countries are needed to slow global warming, however, research indicates students give very few examples when asked which sectors (energy, health, economy) will be effected and how.²² • Confusion about the international Kyoto Protocol exists ranging from the view that the accord will have no effect on the problem to the accord will address the problem. Climate change in fact will require a very long term approach that will span generations.²³

Grade Grouping: Grades 10 to 12

Fundamental Concepts By the end of this level of schooling students should know:	Related Skills/Life Practices
<p>Weather and Climate</p> <ul style="list-style-type: none"> • Weather (in the short term) and climate (in the long term) involve the transfer of heat energy in and out of the atmosphere, resulting in winds and ocean currents.²⁴ • Global climate is an example of a complex natural system. The climate system has properties such as feedback and delay that make it more complex than its individual parts. As with all complex systems, it is not always possible to accurately predict the result of changing once part or process in the climate system.²⁵ • The global climate system is regulated by feedback mechanisms.²⁶ • The global carbon cycle is an important component of the global climate system.²⁷ • Global climate has changed in the past, often slowly but at times abruptly.²⁸ <p>Influence of Weather and Climate</p> <ul style="list-style-type: none"> • Ecosystems always change when climate changes.²⁹ S&T • The development of societies is related to the climatic factors for the region they occupy.³⁰ <p>Human Impact on Climate</p> <ul style="list-style-type: none"> • Scientific investigations reveal that at no time has the earth's temperature changed as rapidly as it has in the 20th century and that this is a result of human activity.³¹ • The scale of human activity that influences climate is determined by the human population level and the level of economic activity and consumption that people are engaged in. The global ecosystem is only able to absorb a portion of the CO₂ generated by the current population and level of economic activity.³² • Abrupt climate change is possible if system thresholds are exceeded.³³ <p>Climate Change Impact -past, present, future</p> <ul style="list-style-type: none"> • Scientists use various methods including computer models to forecast future climate change and potential ecological outcomes associated with it.³⁴ • No response or inadequate response to human induced climate change will result in devastating changes to geophysical cycles, ecosystems and human socio-economic systems.³⁵ • Climate change will affect the various regions of Canada differently.³⁶ • Climate change impact will affect regions of the world to different degrees and have great impact on future generations. ³⁷ 	<p>Securing Information</p> <ul style="list-style-type: none"> • Access online sources of information to determine the rationale of those who support and oppose climate change. <p>Communication</p> <ul style="list-style-type: none"> • Correctly use the following terms verbally and in writing: carbon tax, carbon emissions trading. • Communicate to others (ex. community members) the variety of ways in which individual's impact climate change and possible solutions. <p>Measurement and Data</p> <ul style="list-style-type: none"> • Locate and use graphic presentation of climate data spanning the past to the present to understand the range of future possibilities. • Compare the differences of greenhouse gas emissions from different countries, developed and developing. <p>Analysis</p> <ul style="list-style-type: none"> • Use graphic methods to show the links between atmospheric carbon, ecological processes and human activity <p>Evaluation</p> <ul style="list-style-type: none"> • Rank various human practices for their contribution to greenhouse gas emissions. (Transportation, waste

Fundamental Concepts By the end of this level of schooling students should know:	Related Skills/Life Practices
<p>Responses to climate change</p> <ul style="list-style-type: none"> • The scientific community has predicted human induced climate change since 1827 based on their understanding of global climatic processes. Today the entire scientific community with expertise in climate science accepts that human induced climate change is a severe challenge that must be addressed.³⁸ • The climate change problem is an example of the “tragedy of the commons”. Each individual who contributes to the problem through life actions that result in increased carbon dioxide levels benefits personally from those actions (consuming more, using carbon based fuels, traveling), however the negative results to the climate system are borne by everyone. Solutions to “tragedy of the commons” problems are social challenges that have a history of not being addressed successfully.³⁹ • People respond to climate change in different ways. The world’s scientific community acknowledges that human activity is causing abnormal climate change and call for significant change to address this.⁴⁰ Other sectors of society do not accept the evidence of the science community for a number of reasons or do not accept the changes that are proposed for a number of reasons. This is a major dilemma. • The position on climate change of the mainstream media is significantly different than that held by the science community. This influences the views people have on climate change.⁴¹ • Various groups use a variety of means to prevent action on climate change for a variety of reasons.⁴² • Actions that can reduce the human contribution to climate change can occur from the individual to the international level.⁴³ • Carbon taxes are proposed as a means of building in the cost of carbon dioxide pollution in the price of carbon based fuels (natural gas, coal, oil) to engage market forces to assist in moving away from carbon based fuels. Opinions vary on how carbon taxes would affect economic activity.⁴⁴ • Emission trading systems offer a means of reducing the use of carbon based fuels for the lowest cost and rewarding those who achieve carbon dioxide reductions.⁴⁵ • At this point some level of climate change cannot be avoided and so people must also consider how we can prepare for it.⁴⁶ 	<p>management, recreation, trade, land use, urban design etc).</p> <p>Plan/Design/Build</p> <ul style="list-style-type: none"> • Create a model community plan to successfully address the climate change challenge.

Grade Grouping: Grades 10 to 12

Societal Perspectives	Classroom Level Instructional Notes
<ul style="list-style-type: none"> Climate change will be better addressed by future generations when better technology will be available.⁴⁷ / Climate change is our most serious global challenge. At best any delay in response will make the matter worse for future generations and at worst we may pass critical climate thresholds that may result in abrupt and irreversible climate changes. Canada's winters are too severe. A warming climate will benefit us by reducing heating expenses, extending the growing season and making life more pleasant.⁴⁸ / Climate change is causing serious stresses to ecosystems and will result in demise of many native plants and animals, and reduce agricultural output in many regions. Human induced changes to the climate should not be tolerated. Climate change is an example of a "Tragedy of the Commons". We need to envision far reaching policies and practices to overcome the reach of the individual at the expense of global community.⁴⁹ / Technology and the power of the marketplace will provide mechanisms to give individuals choices to respond to any climate change problems that might develop. The scientific community has the procedures and expertise to best understand climate change and the actions we should take to prevent it. / The news media provides a more balanced view of climate change by including the views of many sectors of society.⁵⁰ The estimated cost of changes that are needed to stop Global Warming and therefore Climate Change are so high (an estimated 60%– 80% decrease in fossil fuel emissions required) it is unreasonable to expect industries, individuals and governments to agree on making even small changes. / The energy reductions needed to address climate change would only require us to reduce use to that of the 1960s, a time of relatively high affluence.⁵¹ 	<ul style="list-style-type: none"> Graphs and equations are useful ways for depicting and analyzing patterns of change.⁵² Create a large scale visual representation of the carbon cycle. Note the major interventions related to human induced rapid climate change. Have the work displayed in a public location. Review and analyze web sites of those who support the science of climate change and those who do not. Organize a formal debate with sides representing different interest groups such as industries, environmentalists and scientists considering solutions to climate change. Evaluate climate change views and responses presented by various scientists, agencies, and industries for their bias and effectiveness. Develop criteria for what a 'successful' climate change model would look like and how it should be used. Review Garrett Hardin's Essay, <i>The Tragedy of the Commons</i>⁵³ and relate it to the Climate Change problem. Compare climate change with other commons' tragedies. Keep climate change journals noting thoughts on personal, community and international climate change deliberations and events? Use these as a basis for group discussion. Identify and promote members of the community who have made a positive contribution to alleviating their impact on climate change and engage in activities to share their contributions⁵⁴ Determine using video, interviews and research the impact of climate change on Arctic communities, coastal nations and island nations.⁵⁵

Grade Grouping: Grades 7 to 9

Exemplary Learning Programs	Developmental Readiness and Major Misconceptions
<p>Weather Scope: An investigative Study of Weather and Climate</p> <p>http://www.k12science.org/curriculum/weatherproj2/en/activities.shtml - viewed June 18/06</p> <p>This is an Internet-based multidisciplinary project that enriches student's learning experiences through applications of instructional technology. Students use real time weather data to write a report on current weather conditions and the general climate in their area, specifically identifying which factors most affect the daily temperature. The website includes a teacher's guide with lesson plans and information for implementation assistance.</p> <p>The project suggests students contact "experts" with questions via the Internet. The learning activities are hands-on and experimentation based.</p> <p>Main Instructional Methods Employed:</p> <ul style="list-style-type: none"> • Activity-based learning • Project-based learning • Audience beyond the classroom • Integrated Learning • Information technology access • Real world connections <p>Rickshaw or Rowboat? Is Climate Change Coming?: WEBQUEST</p> <p>http://teacherweb.com/BD/AIS_D/Rickshaw_or_Rowboat/h.stm -viewed June 18/06</p> <p>This webquest asks students to form sub-committees and come up with a plan to assist the people of Bangladesh. The question for this webquest is: "How might Bangladeshi citizens survive changes in their climate and environment due to global warming? ". Each sub-committee</p>	<p>Developmental Readiness</p> <ul style="list-style-type: none"> • Students can now consolidate their prior knowledge concerning the planet (its shape and movement), heat energy and climate to begin to form more detailed understandings about global climate systems and the causes of the seasons. However, students should not be expected to fully understand these concepts until later.⁵⁶ • At this level teachers should shift the focus to the nature of the invisible changes in matter (in this case carbon) that underlie visible changes in systems. Observable events are explained as transformations in atoms, molecules, and energy and are followed through systems.⁵⁷ • To understand the science involved in the greenhouse effect these students should have some grasp of the concept of conservation of energy.⁵⁸ • Students can start handling scale factors larger than thousands. This will be used when investigating land and water masses and atmospheric measurements.⁵⁹ <p>Misconceptions</p> <ul style="list-style-type: none"> • These students exhibit a number of misconceptions about how the global weather climate system functions⁶⁰ • <i>Volcanoes naturally release far more CO2 into the atmosphere each year than humans.</i> Untrue, volcanoes release less than 1% of human emissions of carbon dioxide⁶¹ • Clarify the confusion regarding terminology -Climate Change, Global Warming, Greenhouse Effect⁶² • Students also fuse problems and mechanisms into a single environmental construct in which all problems and causes are related.⁶³ This includes mixing up climate change with ozone layer depletion and acid rain. • Use of nuclear power does not contribute carbon dioxide except that related to its mining and refining, which is negligible. Use of nuclear power will not contribute to further climate change but neither will its use reduce that which has already occurred.⁶⁴ • Serious misunderstanding of climate change has been

Exemplary Learning Programs	Developmental Readiness and Major Misconceptions
<p>must produce a presentation that communicates their suggestions for rural Bangladeshis of limited means as to how their lives might change due to global climate change. The audience for the presentation are development NGO's that work in Bangladesh - such as DIFID, PLAN, CARE, and USAID.</p> <p>Main Instructional Methods Employed:</p> <ul style="list-style-type: none"> • Co-operative learning • Alternative perspectives • Analysis 	<p>identified in several studies. Students believe that climate change is linked to littering, water pollution, use of unleaded gasoline, or pesticides.⁶⁵</p> <ul style="list-style-type: none"> • Students do not recognize the scope of the problems that are occurring or will occur with increasing climate change.⁶⁶

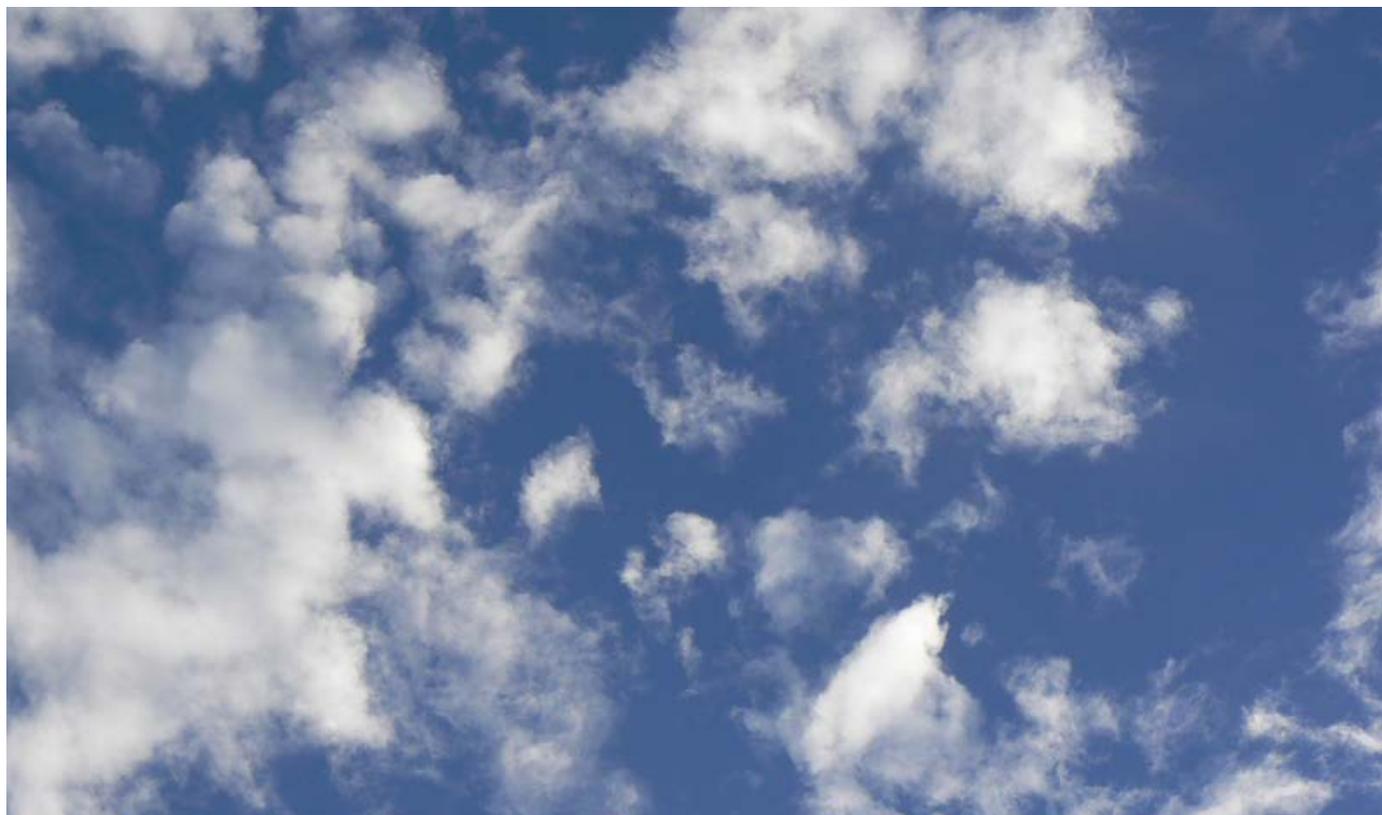
Grade Grouping: Grades 7 to 9

Fundamental Concepts	Related Skills/Life Practices
<p>By the end of this level of schooling students should know:</p> <p>Weather And Climate</p> <ul style="list-style-type: none"> • Local weather occurs in patterns with relatively fast cycles. Seasonal changes in weather have a yearly cycle length.⁶⁷ • Climate throughout the world is determined by system components and processes: differences in intensity of solar energy⁶⁸, heat from the sun resulting in the movement of air masses and ocean currents⁶⁹, the greenhouse effect caused by the atmosphere⁷⁰, variation in land forms (including altitude effects) and the presence of large masses of land and water and the cycling of water⁷¹ and carbon.⁷² • Normal changes in weather and climate can be understood in terms of cycles with varying cycle length or frequency ranging from days to many thousands of years.⁷³ Climates have sometimes changed abruptly in the past as a result of changes in the earth's crust, such as volcanic eruptions or impacts of huge rocks from space.⁷⁴ • The Earth's atmosphere produces a greenhouse effect under normal conditions; that is it allows in more solar radiation than it let's out. Because of this phenomenon, the Earth has relatively stable temperatures that support life.⁷⁵ • Ocean current and atmospheric winds are two mechanisms by which solar generated heat is dispersed around the earth. <p>Influence of weather and climate</p> <ul style="list-style-type: none"> • Normal climate cycles are very long (hundreds to thousands of years) which can allow plants and animals including people, to adapt to the changing conditions. • Climate has a profound impact on people including cultural practices, food preferences, economic activity, and relationships with the natural landscapes.⁷⁶ • Satellite and computer technology are part of a worldwide network that has greatly enhanced our ability to forecast the weather. Despite the technology 	<p>Securing Information</p> <ul style="list-style-type: none"> • Access media reports to determine the range of opinions on climate change. <p>Communication</p> <ul style="list-style-type: none"> • Correctly use the following terms verbally and in writing: greenhouse effect, global warming, climate change⁹⁸, extreme weather.⁹⁹ • Identify suitable community leaders and prepare a formal letter sharing your personal views on climate change and the information supporting it. <p>Measurement and Data</p> <ul style="list-style-type: none"> • Locate and interpret graphic presentations showing the source of human generated CO₂. • Use an online greenhouse gas emissions calculator to grasp personal contributions to the problem. Pool the class

Fundamental Concepts By the end of this level of schooling students should know:	Related Skills/Life Practices
<p>available, the weather/climate system is not fully understood and cannot be perfectly predicted.</p> <p>Human Impact on Climate</p> <ul style="list-style-type: none"> • Global warming refers to the increase in the temperature of the Earth as a result of human activity. Climate change refers to a wide range of phenomena that result from global warming.⁷⁷ • The climate change crisis is an energy (due primarily to the use of carbon based fossil fuels) and land use/deforestation crisis (due to the release of carbon previously stored in wood).⁷⁸ • The atmosphere and the oceans have a limited capacity to absorb carbon dioxide.⁷⁹ • The climate change currently underway is the result of human activity that started as long as 200 years ago. Human actions occurring today will cause further changes to the global climate system in the future.⁸⁰ <p>Climate Change Impact</p> <ul style="list-style-type: none"> • Geophysical changes related to climate change occurring as a result of human activity include: increase in temperatures⁸¹, increase in severe weather events, changes in ocean currents, reduction in the size of glaciers and the polar ice caps, increase in ocean temperatures⁸², loss of permafrost⁸³, sea level changes and melting sea ice⁸⁴, and changes in rainfall patterns. • Ecosystem climate change impacts include: decrease in biodiversity⁸⁵, erosion of northern coastlines, desertification, impacts on forests and vegetation⁸⁶, impact on the workers in our ecosystems (such as pollinators, seed dispersers, and organisms that serve as biological control agents)⁸⁷, loss of coral reefs.⁸⁸ • Socio economic climate change impacts include: desertification and loss of food sources in sub Sahara Africa⁸⁹, impacts on crops, loss of game species in the artic-traditional foods for Inuit⁹⁰, spread of disease carrying organisms from central latitudes to previously colder regions⁹¹, reduction in generating capacity of hydroelectric facilities due to decreases in rainfall.⁹² <p>Responses to climate change</p> <ul style="list-style-type: none"> • The human activities that have led to climate change are also responsible for other serious problems including: smog, acid rain, depletion of the ozone layer as well as over dependence on fossil fuels and a lack of energy independence. Addressing the causes of climate change will also help reduce the severity of these problems as well.⁹³ • The response to climate change by various groups differs. Climate Change is accepted by the scientific community⁹⁴, denied by many members of the corporate community, accepted and denied by various governments⁹⁵. A variety of reasons account for the denial of climate change despite the position of the world's scientific community.⁹⁶ • Many individuals, groups, businesses and governments have taken action to address the climate change challenge to humanity.⁹⁷ 	<p>results and share with others.</p> <p>Analysis</p> <ul style="list-style-type: none"> • List the costs and benefits of increasing temperatures for your region of the country. <p>Evaluation</p> <ul style="list-style-type: none"> • Rate various Canadian climates from best to worst including parameters such as economic, environmental and social impact. Justify your decisions and present to others in class. <p>Plan/Design/Build</p> <ul style="list-style-type: none"> • Design a model using a globe that portrays the factors affecting climate for your region.

Grade Grouping: Grades 7 to 9

Societal Perspectives	Classroom Level Instructional Notes
<ul style="list-style-type: none"> • It is the responsibility of government and industry to change the laws and use the technology that will reduce the use of fossil fuels. /It is the responsibility of individuals to make changes in their personal and family life that will reduce the use of fossil fuels.¹⁰⁰ • Each of us has the right to do as we please regardless of how it affects others. /The present and future health of all living things including people is in jeopardy due to climate change. Under these conditions we must ensure that all people take measures to reduce climate change using whatever means possible.¹⁰¹ • Science is only one way of knowing how the world works and it cannot explain everything and often makes mistakes (for example the Y2K fiasco). /Science has objective procedures and tools that provide the means of learning how the world works. It cannot solve all human problems but has the capacity to identify and explain them so that informed decisions can be made. 	<ul style="list-style-type: none"> • Use graphic representations of data collected over long periods of time to understand the changes in local weather and climate from the past to the present and predict what will occur from the present to the future. • Prepare interview questions in advance then use a school speakerphone to conduct telephone interviews with those involved in Climate Change science. • Compare the energy transfer factors that occur in a greenhouse and the atmosphere. Identify how they are the same and different.¹⁰²



Grade Grouping: Grades 4 to 6

Exemplary Learning Programs	Developmental Readiness and Major Misconceptions
<p>Weather: Unit Summary</p> <p>http://www97.intel.com/en/ThinkingTools/SeeingReason/ProjectExamples/UnitPlans/Weather/</p> <p>After taking on the role of meteorologists, students explore the causes of weather. They are assigned various cities across the globe and must gather information to determine the factors affecting local weather conditions. With this information they must make informed decisions about safety during weather phenomena. Student groups present their findings to the class and individually write a report on a weather phenomenon for someone affected by weather in their assigned city (travel agents, travelers, citizens of those countries or city workers).</p> <p>Main Instructional Methods Employed:</p> <ul style="list-style-type: none"> • Co-operative Learning • Audience beyond the classroom • Higher Order Thinking <p>School Wide Weather Station</p> <p>http://newton.nap.edu/html/nses/html/weather6c.html -viewed June 15/06</p> <p>This year-long project involves the creation of a school Weather Station where students collect data 2 times a day to put in graph and chart form. Every 2 months the data is analysed and the patterns of daily and seasonal temperature, wind speed and direction, precipitation, and humidity are discovered.</p> <p>Main Instructional Methods Employed:</p> <ul style="list-style-type: none"> • Project-based learning • Integrated Learning 	<p>Developmental Readiness</p> <ul style="list-style-type: none"> • These students can start investigations to understand the connections between liquid, solid and gaseous forms of water so that in time they will be able to understand evaporation, condensation, and conservation of matter in their understanding of weather and climate.¹⁰³ • With special instruction these students can identify air as the final destination of water that evaporates. The mechanism of condensation is not understood until early high school.¹⁰⁴ • Students at this age can understand that a globe is a model of the earth and they are presently somewhere on that model as other people around the world are in other areas of the model. For example, we are near the Great Lakes in Canada. The general idea that models represent something else is appropriate for this age.¹⁰⁵ <p>Misconceptions</p> <ul style="list-style-type: none"> • Students ideas about clouds come from observations they have had up to this age. Many books, the news and common language about clouds reaffirm some of their ideas. They have made connections between water and clouds and understand them as individual parts however they are unable at this age to understand the interactions involved between phenomena that create the weather we experience and the water cycle.¹⁰⁶ • Students experience rain often and therefore have ideas about where it comes from. Misconceptions come from students understanding of gravity and weight (heavy things fall) and their lack of understanding of evaporation and condensation.¹⁰⁷ • Research indicates one of the most common misconceptions amongst children and adults is the belief that the cause of the seasons is the distance from the Earth to the sun changing. Misleading diagrams in textbooks and personal experiences with distance and heat has fed these misconceptions. The seasonal variation is a result of the Earth's alignment on its axis and its yearly rotation around the sun.¹⁰⁸ • <i>Cold days are caused by the clouds covering the sun. Snow and ice make it cold.</i> The temperature of a given day is dependent upon many different things including time of year, location, altitude, prevailing winds, etc.¹⁰⁹

Grade Grouping: Grades 4 to 6

Fundamental Concepts By the end of this level of schooling students should know:	Related Skills
<p>Weather and Climate</p> <ul style="list-style-type: none"> • Weather is the combination of the conditions in the atmosphere for any location and includes humidity, temperature, precipitation, cloud cover, visibility and wind. Daily weather changes can occur quickly. Weather patterns change slowly with the seasons.¹¹⁰ • Climate is the characteristic weather patterns that occur in a region determined over a long period of time. The climate for a large area is shaped by where the area is positioned on the Earth, the amount of land and sea area nearby, the altitude, landforms, and the influence of ocean currents.¹¹¹ • Heat energy from the sun is a major determinant of weather/climate patterns. • Weather conditions can vary due to local effects such as tree cover, human activities, pavement and the number and age of buildings.¹¹² • Each season has its own weather characteristics.¹¹³ <p>Influence of Weather and Climate</p> <ul style="list-style-type: none"> • Weather and climate determine which plants and animals live in a region.¹¹⁴ • People are dependent on weather and climate. The kinds of crops that can be grown in an area are determined by the climate.¹¹⁵ • We cannot control weather so people use many tools and behaviours to respond to the weather: build greenhouses to grow crops, clothing, migrate, shelter, heating and cooling systems. • Many tools are used to measure and forecast the weather. • Weather forecasts are helpful in planning outdoor activities (safety issues, travel, farm & yard work, clothing, smog alerts) 	<p>Securing Information</p> <ul style="list-style-type: none"> • Read newspaper weather maps and information to locate common measures: humidity, temperature, precipitation, cloud cover, visibility and wind. • Use almanacs to find out the average temperatures, the agricultural growing conditions, precipitation and storms during various years. Compare regions and years within the class. <p>Communication</p> <ul style="list-style-type: none"> • Correctly use the following terms verbally and in writing: Climate, weather, precipitation • Participate in a pen pal program online where the students can share the weather information with students in other areas in the country or around the world. Maintain records of the weather described by your pen pal.¹¹⁶ <p>Measurement and Data</p> <ul style="list-style-type: none"> • Collect weather data over short and long periods of time and use appropriate graphic techniques to determine patterns and extent of variations. <p>Analysis</p> <ul style="list-style-type: none"> • Use graphic tools to understand and compare the patterns of the weather during seasons. Examine graphs of weather for a season and find patterns. <p>Evaluation</p> <ul style="list-style-type: none"> • Assess the accuracy of the weather forecasts in the newspaper. Compare the forecasts with what the day was actually like. <p>Plan/Design/Build</p> <ul style="list-style-type: none"> • Build a model greenhouse and measure inside and outside temperatures. Make modifications to maximize heat gain.

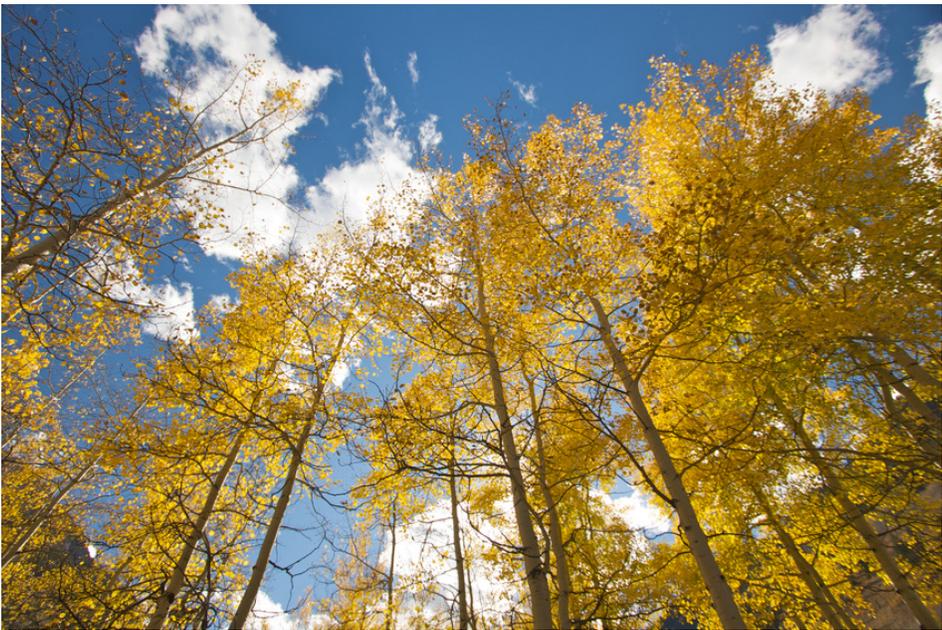
Grade Grouping: Grades 4 to 6

Societal Perspectives	Classroom Level Instructional Notes
<ul style="list-style-type: none"> • Canada has 4 great seasons that allow Canadians to do many different things. /Canada’s winters are too cold and summers are too hot. • Rain stops us from doing things outdoors and is bothersome/Rain is wonderful because it is needed for plants to grow to give us food. 	<ul style="list-style-type: none"> • Measure changes in weather parameters over time and determine cycles over various periods (ex temperature cycles over 24 hours, shadow length, day length over a month –determine the characteristics of these cycles –period, frequency, etc)¹¹⁷ • Students can work together in small groups to make physical models and explain what the models show. For example create a model greenhouse using a shoebox, black lining paper and plastic wrap and determine the characteristics that allow it to modify weather conditions for growing plants.¹¹⁸ • Students can record observations and measurements of the weather in personal journals and upon further reflection add explanations for their journal entries. • Guide students to keep a class weather season journal with biweekly observations and entries. Follow changes throughout the season (record weather observations, related plant and animal activity, impact on people, predictions for the next 2 weeks).¹¹⁹ • Have students follow seasonal changes with online programs such as Plantwatch (www.naturewatch.ca/english/plantwatch) that track plants and animals responding to spring from the south to the north.¹²⁰ • Track the climate-food link by identifying those plant food crops that are available locally throughout the year. • Use a flashlight and a tilted globe to create a sun/earth model that explains the seasons. Use markers stuck on the globe to show where the students are and the season they are experiencing. Use other countries students know to mark different areas of the world.¹²¹

Grade Grouping: Grades 1 to 3

Exemplary Learning Programs	Developmental Readiness and Major Misconceptions
<p>Hello, Sun! (K-2)</p> <p>Everyday Classroom Learning Tools: http://www.harvard.edu/ECT/Hello/hello.html#intro - Viewed May 11 2006</p> <p>An inquiry based activity where students observe the location of the sun in the sky at different times of the day in their schoolyard and the shadows made by the sun. The activity begins by the teacher going outside and modelling the way in which a drawing can help track where the sun is. The class and teacher face south and the teacher makes notes of where the sun is compared to other things in the schoolyard to help children perceive the sun's movement in the sky.</p> <p>Later, students can make their own drawings of these observations and compare them in different months of the year. This very basic activity encourages self-discovery of important scientific ideas such as the movement of the sun and shadows made by the sun.</p> <p>The classroom teacher is helping students with their ideas about the sun and shadows by using questioning techniques about the students observations encouraging them to seek alternative ideas to what they think is happening. This activity will help students later when they are learning about the reason for the seasons.¹²²</p> <p>Main Instructional Methods Employed:</p> <ul style="list-style-type: none"> • Higher Order Thinking • Activity Based Learning 	<p>Developmental Readiness</p> <ul style="list-style-type: none"> • These students should be come familiar with many phenomena including weather and seasons without having the concept of cycles or systems imposed on them. This will come in middle school and high school.¹²³ • Instruction should aim to familiarize students with many Earth related phenomenon which they only come to understand later, in middle school, as cyclic. The water cycle should not be addressed until they are older.¹²⁴ • Children at this age think of properties of a system as belonging to individual parts rather than coming from the interaction of the parts. For example, the individual parts of the water cycle such as clouds, rain and oceans can be understood independent of their interactions with each other. It is a challenge for them to understand something that comes from the interaction of parts.¹²⁵ • Children are learning about the appearance/reality distinction. This means that things are not always as they appear. Helping children make observations that eventually get them to question appearance versus reality presents a good developmental fit.¹²⁶¹²⁷ <p>Misconceptions</p> <ul style="list-style-type: none"> • Children at this age see clouds as an independent concept and not part of a cycle.¹²⁸ • Children create many personally meaningful ideas of the natural phenomenon of rain using concepts they have already learned in their life. Rain is part of the complex water cycle and should not be discussed in this context with students until middle school.¹²⁹

Grade Grouping: Grades 1 to 3

Fundamental Concepts and Subject Area Affiliation By the end of this level of schooling students should know:	Related Skills/Life Practices
<p>Weather and Climate</p> <ul style="list-style-type: none"> • Weather changes from day to day but there are patterns over time (in type of rain or snow, temperature highs and lows, day length). Some changes we can see and some are too slow to notice. We can use tools to follow these slow changes. Some weather events however do not seem to follow a pattern.¹³⁰ • Daily weather changes with the seasons. • The sun warms the land, air, and water.¹³¹ <p>Influence of Weather and Climate</p> <ul style="list-style-type: none"> • People and other animals and plants do things to be able to live with the weather as it changes throughout the year.¹³² • People can't change the weather so we adapt by building, clothing, heating systems and going south. • Knowing what the weather will be or knowing the weather prediction for the future helps us plan our activities, our clothes and our travel plans. Knowing the weather also helps us keep safe in our environment. 	<p>Securing Information</p> <ul style="list-style-type: none"> • Complete schoolyard observations of natural phenomenon such as observing where the sun is in the sky and the changes in the schoolyard trees, plants and flowers during different months of the year.¹³³ <p>Communication</p> <ul style="list-style-type: none"> • Correctly use the following terms verbally and in writing: weather, liquid, solid, temperature <p>Measurement and Data</p> <ul style="list-style-type: none"> • Keep daily records of temperature (hot, cold, pleasant), rain or snowfall (none some lots) and plot by week, day month.¹³⁴ <p>Analysis</p> <ul style="list-style-type: none"> • Prepare a table of the 4 seasons and identify the activities of people, other animals and plants for each season. <p>Evaluation</p> <ul style="list-style-type: none"> • Recommend items and clothing to keep you safe and comfortable for each season.¹³⁵ <p>Plan/Design/Build/Use</p> <ul style="list-style-type: none"> • Plan a wardrobe for the whole year and illustrate it for the 4 seasons

Grade Grouping: Grades 1 to 3

Societal Perspectives	Classroom Level Instructional Notes
<p>The weather impacts people in many different ways.</p> <p>Weather is not good or bad. We need all kinds of weather for plants, animals & people to live.</p> <p>Some weather is bad because people can't do what they want to.</p>	<ul style="list-style-type: none"> • Note weather and related phenomena (light level, sun position, shadows), at the start of each school day and the changes that take place over the day. • Use drawings to allow students to express the details of the weather in the day. • Track daily and seasonal weather changes noting the difference in the rate of change.¹³⁶ • Note how weather impacts school sports, clothing selected and other phenomena at key points throughout the school year. Record using digital photographs and compare. • Follow the changes in schoolyard trees recording in booklet form observations made in September or June (summer), October (fall), January (winter) and late April-early May (spring). • Create a food calendar of what locally grown food is available over the school year. Relate to seasonal weather changes.

WEATHER, CLIMATE, CLIMATE CHANGE LEARNING PROGRESSION

1.) WEATHER AND CLIMATE

	1 to 3	4 to 6	7 to 9	10 to 12
<p>Weather</p>	<ul style="list-style-type: none"> • Weather changes from day to day but there are patterns over time (in type of rain or snow, temperature highs and lows, day length). Some changes we can see and some are too slow to notice. We can use tools to follow these slow changes. Some weather events however do not seem to follow a pattern.¹³⁷ 	<ul style="list-style-type: none"> • Weather is the combination of the conditions in the atmosphere for any location and includes humidity, temperature, precipitation, cloud cover, visibility and wind. Daily weather changes can occur quickly. Weather patterns change slowly with the seasons.¹³⁸ • Weather conditions can vary due to local effects such as tree cover, human activities, pavement and the number and age of buildings.¹³⁹ 	<ul style="list-style-type: none"> • Local weather occurs in patterns with relatively fast cycles. Seasonal changes in weather have a yearly cycle length.¹⁴⁰ 	

	1 to 3	4 to 6	7 to 9	10 to 12
Climate		<ul style="list-style-type: none"> Climate is the characteristic weather patterns that occur in a region determined over a long period of time. The climate for a large area is shaped by where the area is positioned on the Earth, the amount of land and sea area nearby, the altitude, landforms, and the influence of ocean currents.¹⁴¹ 	<ul style="list-style-type: none"> Climate throughout the world is determined by system components and processes: differences in intensity of solar energy¹⁴², heat from the sun resulting in the movement of air masses and ocean currents,¹⁴³ the greenhouse effect caused by the atmosphere¹⁴⁴, variation in land forms (including altitude effects) and the presence of large masses of land and water and the cycling of water¹⁴⁵ and carbon.¹⁴⁶ 	<ul style="list-style-type: none"> Global climate is an example of a complex natural system. The climate system has properties such as feedback and delay that make it more complex than its individual parts. As with all complex systems, it is not always possible to accurately predict the result of changing once part or process in the climate system.¹⁴⁷ The global climate system is regulated by feedback mechanisms.¹⁴⁸ Global climate has changed in the past, often slowly but at times abruptly.¹⁴⁹ The global carbon cycle is an important component of the global climate system.¹⁵⁰
The Sun's Energy	<ul style="list-style-type: none"> The sun warms the land, air, and water.¹⁵¹ 	<ul style="list-style-type: none"> Heat energy from the sun is a major determinant of weather/climate patterns. 	<ul style="list-style-type: none"> The Earth's atmosphere produces a greenhouse effect under normal conditions; that is it allows in more solar radiation than it lets out. Because of this phenomenon, the Earth has relatively stable temperatures that support life. Ocean current and atmospheric winds are two mechanisms by which solar generated heat is dispersed around the earth. 	<ul style="list-style-type: none"> Weather (in the short term) and climate (in the long term) involve the transfer of heat energy in and out of the atmosphere, resulting in winds and ocean currents.¹⁵²
Seasons and Cycles	<ul style="list-style-type: none"> Daily weather changes with the seasons. 	<ul style="list-style-type: none"> Each season has its own weather characteristics.¹⁵³ 	<ul style="list-style-type: none"> Normal changes in weather and climate can be understood in terms of cycles with varying cycle length or frequency ranging from days to many thousands of years.¹⁵⁴ Climates have sometimes changed abruptly in the past as a result of changes in the earth's crust, such as volcanic eruptions or impacts of huge rocks from space.¹⁵⁵ 	

2.) HUMAN IMPACT ON CLIMATE CHANGE

1 to 3	4 to 6	7 to 9	10 to 12
		<ul style="list-style-type: none"> • Global warming refers to the increase in the temperature of the Earth as a result of human activity. Climate change refers to a wide range of phenomena that result from global warming.¹⁵⁶ • The climate change crisis is an energy (due primarily to the use of carbon based fossil fuels) and land use/deforestation crisis (due to the release of carbon previously stored in wood).¹⁵⁷ • The climate change currently underway is the result of human activity that started as long as 200 years ago. Human actions occurring today will cause further changes to the global climate system in the future.¹⁵⁸ • The atmosphere and the oceans have a limited capacity to absorb carbon dioxide.¹⁵⁹ 	<ul style="list-style-type: none"> • Scientific investigations reveal that at no time has the earth's temperature changed as rapidly as it has in the 20th century and that this is a result of human activity.¹⁶⁰ • The scale of human activity that influences climate is determined by the human population level and the level of economic activity and consumption that people are engaged in. The global ecosystem is only able to absorb a portion of the CO₂ generated by the current population and level of economic activity.¹⁶¹ • Abrupt climate change is possible if system thresholds are exceeded.¹⁶²

3.) CLIMATE CHANGE IMPACT

1 to 3	4 to 6	7 to 9	10 to 12
		<ul style="list-style-type: none"> • Geophysical changes related to climate change occurring as a result of human activity include: increase in temperatures¹⁶³, increase in severe weather events, changes in ocean currents, reduction in the size of glaciers and the polar ice caps, increase in ocean temperatures¹⁶⁴, loss of permafrost¹⁶⁵, sea level changes and melting sea ice¹⁶⁶, and changes in rainfall patterns. • Ecosystem climate change impacts include: decrease in biodiversity¹⁶⁷, erosion of northern coastlines, desertification, impacts on forests and vegetation¹⁶⁸, impact on the workers in our ecosystems (such as pollinators, seed dispersers, and organisms that serve as biological control agents)¹⁶⁹, loss of coral reefs.¹⁷⁰ • Socio-economic climate change impacts include: desertification and loss of food sources in sub Sahara Africa¹⁷¹, impacts on crops, loss of game species in the Arctic, traditional foods for Inuit¹⁷², spread of disease-carrying organisms from central latitudes to previously colder regions¹⁷³ and reduction in generating capacity of hydroelectric facilities due to decreases in rainfall.¹⁷⁴ 	<ul style="list-style-type: none"> • Scientists use various methods including computer models to forecast future climate change and potential ecological outcomes associated with it.¹⁷⁵ • No response or inadequate response to human induced climate change will result in devastating changes to geophysical cycles, ecosystems and human socio-economic systems.¹⁷⁶ • Climate change will affect the various regions of Canada differently.¹⁷⁷ • Climate change will affect regions of the world to different degrees and have great impact on future generations.¹⁷⁸

4.) RESPONSES TO CLIMATE CHANGE

1 to 3	4 to 6	7 to 9	10 to 12
		<ul style="list-style-type: none"> The response to climate change by various groups differs. Climate Change is accepted by the scientific community¹⁷⁹, denied by many members of the corporate community, accepted and denied by various governments.¹⁸⁰ A variety of reasons account for the denial of climate change despite the position of the world's scientific community.¹⁸¹ The human activities that have led to climate change are also responsible for other serious problems including: smog, acid rain, depletion of the ozone layer as well as over dependence on fossil fuels and a lack of energy independence. Addressing the causes of climate change will also help reduce the severity of these problems as well.¹⁸² 	<ul style="list-style-type: none"> The scientific community has predicted human induced climate change since 1827 based on their understanding of global climatic processes. Today the entire scientific community with expertise in climate science accepts that human induced climate change is a severe challenge that must be addressed.¹⁸³ The climate change problem is an example of the “tragedy of the commons”. Each individual who contributes to the problem through life actions that result in increased carbon dioxide levels benefits personally from those actions (consuming more, using carbon based fuels, traveling), however the negative results to the climate system are borne by everyone. Solutions to “tragedy of the commons” problems are social challenges that have a history of not being addressed successfully.¹⁸⁴ People respond to climate change in different ways. The world's scientific community acknowledges that human activity is causing abnormal climate change and call for significant change to address this.¹⁸⁵ Other sectors of society do not accept the evidence of the science community for a number of reasons or do not accept the changes that are proposed for a number of reasons. This is a major dilemma. The position on climate change of the mainstream media is significantly different than that held by the science community. This influences the views people have on climate change.¹⁸⁶ Various groups use a variety of means to prevent action on climate change for a variety of reasons.¹⁸⁷

5.) ADDRESSING CLIMATE CHANGE

1 to 3	4 to 6	7 to 9	10 to 12
		<ul style="list-style-type: none"> Many individuals, groups, businesses and governments have taken action to address the climate change challenge to humanity.¹⁸⁸ 	<ul style="list-style-type: none"> Actions that can reduce the human contribution to climate change can occur from the individual to the international level.¹⁸⁹ Carbon taxes are proposed as a means of building in the cost of carbon dioxide pollution in the price of carbon based fuels (natural gas, coal, oil) to engage market forces to assist in moving away from carbon based fuels. Opinions vary on how carbon taxes would affect economic activity.¹⁹⁰ Emission trading systems offer a means of reducing the use of carbon based fuels for the lowest cost and rewarding those who achieve carbon dioxide reductions.¹⁹¹ At this point some level of climate change cannot be avoided and so people must also consider how we can prepare for it.¹⁹²

WEATHER, CLIMATE, AND CLIMATE CHANGE EDUCATIONAL RESOURCES

Weather: A Journey in Nonfiction

- 1 to 3 & 4 to 6 – lists books about weather and literacy activities relating to the fiction and non-fiction stories
http://www.readwritethink.org/lessons/lesson_view.asp?id=219

Weather and Climate

- 7 to 9 'Carbo' the Carbon Atom: Choose your own learning.
It's a great story to introduce or test young peoples knowledge of the carbon cycle.
<http://www.letus.northwestern.edu/projects/gw/cycles/carbo/index.html> - Viewed May 25 2006

Climate Change

- 7 to 9 The Environmental Protection Agency in the United States has an informative child friendly website.
<http://www.epa.gov/globalwarming/kids/index.html> - Viewed May 23 2006

Climate Change North

- 7 to 9 & 10 to 12
<http://www.climatechangenorth.ca>

Climate: A Crisis Averted: A movie clip

- 7-9 & 10-12 – a creative look back at the Climate Crisis from the year 2054.
<http://www.renewus.org/index.html> - viewed June 10, 2006 -a very positive outlook makes this particularly useful in school settings

Climate Change Wheel Card: Printable

- 7 – 9 & 10-12 – great free resource that can help students understand the problem.
[http://yosemite.epa.gov/oar/globalwarming.nsf/UniqueKeyLookup/SHSU5BW1Q7/\\$File/wheelcard.pdf](http://yosemite.epa.gov/oar/globalwarming.nsf/UniqueKeyLookup/SHSU5BW1Q7/$File/wheelcard.pdf) - Viewed June 10, 2006

Climate Protection

- 7 to 9 & 10 to 12
A resource about science, policy and action around Climate Change.
<http://www.greenlearning.ca/climate/climate.php> -Viewed June 1 2006

Critical Analysis of Global Warming

- 10-12 a resource including up-to-date, critically written information about global warming.
<http://www.globalissues.org/EnvIssues/GlobalWarming.asp> -Viewed June 2 2006

The Heat is On (1998) By Ross Gelbspan

- 10-12 A Critical political, economic and media review of the treatment of Climate Change in culture.

The World Climate Report

- 10-12 – a Skeptics point of view of Climate Change and Global Warming
<http://www.worldclimatereport.com/index.php/about-us/> - Viewed June 10, 2006

Skepticism.net

- 10 to 12 – Great for many examples of articles refuting the facts of Climate Change by various interest groups.
www.skepticism.net/faq/environment/global_warming/index.html - Viewed June 27/06

Weather and Climate

- Lesson Plans, information and resources for teaching about Weather and Climate throughout the grade levels
<http://weathereye.kgan.com/index.html>

Pollution Probe. (2004) Primer on Climate Change and Human Health

- Good resource for teachers and students relating to climate change
<http://www.pollutionprobe.org/Reports/climatechangeprimer.pdf> - Viewed September 1 2006

REFERENCES

- Agence France Presse (2005) Global Warming; The Tragedy of the Commons revisited. February 13th 2005. *Common Dreams Newcenter*. <http://www.commondreams.org/headlines05/0213-06.htm> - viewed June 10 2006.
- Alley, B.(2000) *Two-Mile Time Machine*. Princeton University Press, USA.
- AAAS, American Association for the Advancement of Science, (1993) *Benchmarks for Science Literacy*, Project 2061, Oxford University Press, New York.
- Anderson, C.W., L. Mohan, and A.Sharma.(2005) *Developing a Learning Progression for Carbon Cycling in Environmental Systems*. Pathways to Scientific Teaching in Ecological Education, Ecological Society of America, Montreal, Canada.
- Andersson, Björn and Anita Wallin. (2000) Students' understanding of the greenhouse effect, the societal consequences of reducing CO₂ emissions and the problem of ozone layer depletion, *Journal of Research in Science Teaching* 1096-1111.
- Bad Astronomy. (2006) <http://www.badastronomy.com/bad/misc/seasons.html> - Viewed May 11, 2006
- Boyes, E, Chuckran, D. and Stanisstreet, M. (1993) "How Do High School Students Perceive Global Climatic Change: What are Its Manifestations? What Are Its Origins? What Corrective Action Can Be Taken? *Journal of Science Education and Technology* 2:4: 551-557.
- Bryner, Jeanna.(1999) "Why Does Ice Float?" *Instructor* 115:4 (December 2005): 42-43.
- Carter, L. (1998) Global Environmental Change: Modifying Human Contributions Through Education. *Journal of Science Education and Technology*. Vol 7, No. 4, December 1998. 297-309
- Corbett, J & Durfee, J. (2004) *Testing Public (Un)Certainty of Science :Media Representations of Global Warming*. *Science Communication*, Vol. 26 No. 2, December 2004.130.
- Cordero, Eugene C.(2002) "Is the Ozone Hole Over Your Classroom? *Australian Science Teachers Journal* 48:1 (March): 34-39.
- Coward H. & Weaver A. (ed.)(2004) *Hard Choices: Climate Change in Canada*. The Centre for Studies in Religion and Society. Waterloo, 92.

- Dale, V. H. (1997) The Relationship Between Land-Use Change and Climate Change. *Ecological Applications*, Vol 7, No 3. (AUG 1997)
- Dispensa J.M. & Brulle, R (2003) Media's social construction of environmental issues: Focus on global warming: *The International Journal of Sociology and Social Policy*; 2003; 23, 10; ABI/INFORM Global. 74-80
- Du Pont, P. (2006) Don't be Very Worried. Tuesday, May 23, 2006. *Liberty Matters*.
http://www.libertymatters.org/newsservice/2006/faxback/3009_truth.htm - viewed June 21/06.
- Fenge, T.(2001) Inuit and Climate Change. *Isuma: Canadian Journal of Policy Research*. Vol 2, No 4, Winter.
- Francis, D & Hengeveld, (1998) H. Extreme Weather and Climate Change. Atmospheric Environment Service. Environment Canada.
- Fraser, A.B. (2006) College of Earth and Mineral Sciences.
<http://www.ems.psu.edu/~fraser/Bad/BadGreenhouse.html> - viewed June 22 2006.
- Galbraith, H & Parmesan, C. (2004) Observed Impacts of Global Climate Change in the US. Pew Center on Global Climate Change. November 2004. 6.
- Godrej, Dinyar.(2001) the No-nonsense guide to climate change. New Internationalist, Toronto, 2001.
- Greenlearning.ca. The Pembina Institute (2006) <http://www.greenlearning.ca/climate-change/index.php>-viewed June 3 2006.
- Harrison, G.P., Whittington,H.W. & Gundry, S.W. (1998) Climate Change Impacts on Hydroelectric Power. School of Engineering and Electronics. The University of Edinburgh. – Viewed September 1 2006.
- Harvard-Smithsonian Center for Astrophysics: High Energy Astrophysics Division (2006). The Everyday Classroom Tools curriculum, the Threads of Inquiry.<http://hea-www.harvard.edu/ECT/thrintro.html> - Viewed May 9, 2006
- Henriques, Laura. (2002) “Children’s Ideas About Weather: A Review of the Literature.” *School Science and Mathematics* 102:5 (May 2002): 202-215.
- Henriques, L. (2000) Children's misconceptions about weather: A review of the literature. (April 2000) California State University Long Beach. <http://www.csulb.edu/%7EElhenriqu/NARST2000.htm> -viewed May 03 2006
- Hengeveld H, Bush E. and Edwards, P. (2002) Environment Canada. Frequently Asked Questions about the Science of Climate Change.
- Henry, A. (2000) Public Perceptions of Global Warming. *Research in Human Ecology*, Vol 7, No 1. 25-30.
- Holmes, B. (2005) Ocean Heat Store Makes Climate Change Inevitable. March 2005.
<http://www.newscientist.com/article.ns?id=dn7161> - viewed June 25/06
- Hoegh-Guldberg, O. (1999) Climate Change, coral bleaching and the future of the world’s coral reefs. *The Reef Education Network*. <http://www.reef.edu.au/OHG/res-pic/HG%20papers/Hoegh-Guldberg%201999.pdf> - viewed June 20th 2006.

- Huebert, R. (2001) Climate Change and Canadian Sovereignty in the Northwest Passage. *Canadian Journal of Policy Research*. Vol 2, No. 4, Winter 2001.87
- Hulme, Mike (2003) Abrupt climate change: can society cope? *The Royal Society*. July 2003.
<http://www.journals.royalsoc.ac.uk/media/n9a4b9f0n1uume84x2m/contributions/7/g/2/d/7g2d968h7a9y0k30.pdf> - viewed August 28 2006.
- International Council of Science. (2006) www.icsu.org. - viewed August 30 2006.
- IPCC, 2001: *Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change* [Houghton, J.T.,Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, and C.A. Johnson (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 25.
- Koulaidis, Vasilis and Vasilla Christidou.(1999) "Models of Students' Thinking Concerning the Greenhouse Effect and Teaching Implications." *Science Education* 83:5 (1999): 559- 576.
- May, Lord R. (2005) Climate Change Undeniably Real, Caused By Human Activities. <http://www.ens-newswire.com/ens/nov2005/2005-11-28-insmay.asp> - viewed June 25 2006
- Marland,G, Pielke, R, Appsc, M, Avissar, R, Betts, R, Davis, K, Frumhoff, P, Jackson,S, Joyce, L, Kauppi, P, Katzenberger, J, MacDicken, K, Meilson, R, Niles, J, Dutta, D, Niyogi, S, Norby, R, Pena, N, Sampson, N, Xuer, Y. (2003)The Climate impacts of Land surface change and carbon management, and the implications for climate-change mitigation policy. *Climate Policy* 3 (2003) 149–157, 151.
- Meadows, G and Wiesenmayer, R.(1999) "Identifying and Addressing Students' *Alternative Conceptions of the Causes of Global Warming: The Need for Cognitive Conflict.*" *Journal of Science Education and Technology* 8:3 (1999): 235-9.
- Melinski, M., Semmann, D., Krambeck, H.J.,and Marotzke J., (2006) Stabilizing the Earth's climate is not a losing game: Supporting evidence from public goods experiments. *PNAS*. March 14, 2006. Vol 103, No 11. 3994-3998.
- Moore, G. T. (1998) Global Warming: More Than Hot Air? June 24 1998. *Cato Institute*. <http://www.cato.org/dailys/6-24-98.html> - Viewed June10, 2006
- Moore, G.T. (1998) Warmer Earth Might be a Welcome Trend. April 28, 1998. <http://www.cato.org/dailys/4-28-98.html> -viewed June 21 2006
- New Scientist (2006) <http://www.newscientist.com/channel/earth/climate-change/> - viewed June 6 2006
- NAAEE, North American Association for Environmental Education (2004). *Excellence in Environmental Education – Guidelines for Learning (Pre K-12)* <http://naaee.org/pages/npeee/learnerguidelines/execsum-intro.html>, accessed May 2006
- Perry, M, Arnell, N, Hulme, M, Nicholls, R, Livermore, M. (1998) Adapting to the inevitable. *Nature*, Vol 395, October 1998.

- Pearce, F. (2004) Kyoto Protocol is Just the Beginning. October 2004.
<http://www.newscientist.com/article.ns?id=dn6494> - viewed June 25/06.
- Pojman, L.P. (ed.) (1997) Environmental Ethics. Readings in Theory and Application. Wadsworth Publishing Company, Toronto, 306-307.
- Pollution Probe. (2004) Primer on Climate Change and Human Health,
<http://www.pollutionprobe.org/Reports/climatechangeprimer.pdf> -Viewed September 1 2006.
- Rehdanz, K & Maddison, D. (2003) Climate and Happiness. <http://www.ictp.trieste.it/~eee/seminar/Rehdanz%2005-06-03%20Paper.pdf> - viewed June 21 2006.
- Reiter, P. (2000) From Shakespeare to Defoe: Malaria in England in the Little Ice Age. *Centers for Disease Control and Prevention. Perspectives*. Vol. 6, No. 1 Jan-Feb 2000. <http://www.cdc.gov/ncidod/eid/vol6no1/reiter.htm> - viewed June 27/06
- Skepticism.net. (2006) www.skepticism.net/faq/environment/global_warming/index.html - viewed June 27 2006.
- Smil, Vaclav, (2003) Energy at the Crossroads – Global Perspectives and Uncertainties, MIT Press, Cambridge Mass.
- Stanisstreet, M. and Boyes E. (2004) How can we best reduce global warming? Student's ideas and misconceptions. *International Journal Environmental Studies*, April 2004, Vol. 61(2), pp. 211–222
- Syukuro, M and Stouffer, R. (1993) Century-scale effects of increased atmospheric CO2 on the ocean-atmosphere system. *Nature*; Vol 364, July 15 1993. 215-218.
- Taylor, Jerry. (1997) Hot Air in Kyoto. December 8, 1997. *Cato Institute*. <http://www.cato.org/dailys/12-08-97.html> - viewed June 10, 2006
- Toulin, A. (2002). CANADA: Kyoto possible without hurting economy: CEOs. *Climate Ark*.
<http://www.climateark.org/articles/reader.asp?linkid=13731> -viewed June 21 2006.
- Trumbo, C. (1996) Constructing climate change: claims and frames in US news coverage of an environmental issue. *Public Understanding. Science*. 5 (1996) 269–283.
- United Nations Framework Convention on Climate Change, The. (2006) <http://unfccc.int/2860.php> - view August 28 2006
- Union of Concerned Scientists. (2006) http://www.ucsusa.org/global_warming/- Viewed August 28 2006.
- Walther, G-R, Post, E, Convey, P, Menzel, A, Parmesan, C, Beebee, T, Fromentin, J-M, Guldberg, O H, Bairlein, F. (2002) Ecological Responses to Recent Climate Change. *Nature*, Vol 416. March 2002.
- National Committee on Science Education Standards and Assessment, National Research Council (2006) National Science Education Standards- <http://newton.nap.edu/html/nses/html/6c.html> - --viewed May 03/06

ENDNOTES

¹ This community includes: National Academies of Science for Canada, United States, Britain, Germany, Italy, France, Japan, Russia, Brazil, China, India and others, the American Geophysical Union, American Meteorological Society, NASA's Goddard Institute for Space Studies, the National Oceanic and Atmospheric Administration, the Environmental Protection Agency, the US National Centre for Atmospheric Research, and the Canadian Meteorological and Oceanographic Society, International Council of Science found at www.icsu.org, The United Nations Framework Convention on Climate Change <http://unfccc.int/2860.php> - view August 28 2006 and the Union of Concerned Scientists http://www.ucsusa.org/global_warming/ - Viewed August 28 2006.

² As Nelkin stated, the public understands science "less through direct experience or past education than through the filter of journalistic language and imagery" (1995, 2). Corbett and Durfee, 2004: 130.

³ Milinski et al, 2006.

⁴ Anderson, Mohan and Sharma, 2005: 15.

⁵ Stabilizing the Earth's Climate is not a loosing game: Supporting evidence from public goods experiments. Milinski et al, 2006 and Global Environmental Change: Modifying Human contributions through education. Carter, 1998.

⁶ See Andersson and Wallin, 2000. It has been found that middle and high school teachers are less comfortable integrating content areas than those teachers in the primary grades. Since so much of the content related to weather and climate is geography based instead of science based it behooves us to get social science and natural science teachers communicating. Climate and weather is best taught combining social studies (Geography) instruction with science instruction. Henriques, 2000.

⁷ Anderson, Mohan and Sharma, 2005: 8 and 17.

⁸ NAAEE, 2004: Appendix A 81

⁹ NAAEE, 2004: Appendix A 79

¹⁰ NAAEE, 2004: Appendix A 79

¹¹ NAAEE, 2004: Appendix A 79

¹² NAAEE, 2004: Appendix A 77

¹³ For example in a UK study of students from 3 different age groups found conceptual links between a reduction in global warming and actions that are more generally environmentally friendly but not, in reality, related to global warming, appear to diminish over the increasing age groups. For instance, fewer of the older students held that marine or freshwater pollution, or littering of streets, were linked to global warming. This appears to be an example not just of increased knowledge, but also of a maturation of thinking among older students in that they show increased

discrimination.

¹⁴ NAAEE, 2004: Appendix A 77

¹⁵ These students are also making connections between what they are experiencing and how it affects their lives; how situations in general can affect lives in general. Harvard-Smithsonian Center for Astrophysics: High Energy Astrophysics Division, 2006.

¹⁶ National Committee on Science Education Standards and Assessment, National Research Council, 2006.

- ¹⁷ These students are often eager to find out how things work in the natural world and ask many questions. Harvard-Smithsonian Center for Astrophysics: High Energy Astrophysics Division, 2006.
- ¹⁸ Making observations using one's senses, attending to patterns in ones' environment, and detecting changes and continuity fit well from a developmental standpoint with learning in the early grades. Students at this age are often eager to find out how things work in the natural world and ask many questions. Harvard-Smithsonian Center for Astrophysics: High Energy Astrophysics Division, 2006.
- ¹⁹ Public awareness of global warming is based on broad generalizations from other environmental problems such as ozone depletion and local air pollution. These understandings lead to understandings of climate change that are different from current scientific understanding. Kempton, Bostner and Hartley as mentioned in Henry, 2000. Generalizations are a challenge specifically for the Climate Change issue because of the interactions between complex systems that are making climate change happen. There are many causes of climate change. Boyes, Chuckran and Stanisstreet, 1993: 542. This was also found in a study in research with students in the UK. Stanisstreet and Boyes, 2004: 221, as well as found in Andersson and Wallin, 2000. Scientists themselves are exploring the interactions between ozone depletion and temperature changes. Cordero, 2002: 34-35. However, an example of a misconception that many people have that is not necessarily a misconception is the belief that reducing the use of CFC's will reduce global warming. Stanisstreet and Boyes, 2004. Andersson and Wallin, 2000: 1098 and 1107. Research indicates that emissions of aerosols at certain levels can cool the climate and therefore offset emissions of greenhouse gases making this belief true. This is an example of a negative feedback system and also illustrates the challenges to understanding the science between climate change. Godrej, 2001. Hengeveld, Bush and Edwards, 2002: 7.
- ²⁰ Godrej, 2001: 11. The Industrial Revolution may be said to have begun in the 1780s, after James Watt developed his steam engine. At this time, ice-core records show that levels of carbon dioxide in the atmosphere were around 280 parts per million (ppm). Give or take 10 ppm, this had been their level for the past 6,000 years, since the beginning of the first cities. After the 1780s, as industrialization drove up the burning up of fossil fuels in the developed world, carbon dioxide levels rose. At first the rise was slow. It took about a century and a half to reach 315 ppm. Accelerating during the 20th century, levels reached 330 ppm by the mid-1970s; 360 ppm by the 1990s; 380 ppm today. There are long time lags involved here, which are often not appreciated by those unfamiliar with physical systems. Once in the atmosphere, the characteristic "residence" time of a carbon dioxide molecule is a century. And the time taken for the oceans' expansion to come to equilibrium with a given level of greenhouse warming is several centuries. May, 2005. Even if greenhouse gases never rise beyond their present level, temperatures and sea levels will continue rising for another century or more because of a time lag in the oceans' response to atmospheric temperatures, say researchers. The time lag occurs because rising air temperatures take time to make themselves felt throughout the immense thermal mass of the oceans. This "thermal inertia" means that Earth has not yet felt the full effect of today's level of greenhouse gases, explains Meehl. And because water expands as it warms, this time lag in temperature will continue to push sea level higher. Meehl's models predict that thermal expansion alone would make sea levels rise by about 11 centimetres over the next century, even if greenhouse gases were held at 2000 levels. Holmes, 2005.
- ²¹ This misconception illustrates students' confusion between the roles of vehicle emissions in general and the separate issue of particular pollutants (lead compounds) found in vehicle emissions. Stanisstreet and Boyes, 2004.
- ²² See Andersson and Wallin, 2000.
- ²³ The Kyoto Protocol is an agreement between nations to reduce greenhouse-gas emissions by approximately 5% by 2012. Although the agreement is an important beginning to turning around climate change, it can only play a small role for several reasons. Firstly, the targets concern countries that are presently emitting higher levels of greenhouse gas emissions. The selected 38 countries account for 57 per cent of present global carbon emissions. It is expected that future growth in emissions will occur in the fast-developing regions of Asia and Latin America. These countries were not included in the agreement. Parry et al 1998. Secondly, the 5% goal of Kyoto is not significant enough to stop the concentrations of the gas rising higher. Approximately a cut of 2/3rds is needed. Lastly, the agreement does not provide nations with a clear path and end goal concerning Global Climate Change. Pearce, 2004.
- ²⁴ Solar radiation heats the land masses, oceans, and air. Transfer of heat energy at the boundaries between the atmosphere, the land masses, and the oceans results in layers of different temperatures and densities in both the ocean and atmosphere. The action of gravitational force on regions of different densities causes them to rise or fall – and such circulation, influenced by the rotation of the earth, produces winds and ocean currents." AAAS, 1993: 70.
- ²⁵ The global climate weather system can best be understood through systems analysis. It has boundaries and subsystems, relationships to other systems, and inputs and outputs. AAAS, 1993: 266.

²⁶AAAS, 1993: 266. Positive feedbacks are mechanisms that amplify an effect and negative feedbacks can moderate an effect. Examples of some Feedback Mechanisms involved in Climate Change are: Positive feedback: A warmer atmosphere is expected to contain more water vapour, which is a greenhouse gas, thereby reinforcing the warming. Forest dieback and reduced growth due to stress caused by climate change such as increased temperatures, results in less CO₂ being taken from atmosphere. A possible negative feedback would be that due to higher concentrations of CO₂ in the atmosphere would result in an increased growth in some plants. The IPCC future climate change models predict that the net effect of land and ocean climate feedbacks as indicated is to further increase projected atmospheric CO₂ concentrations, by reducing both the ocean and land uptake of CO₂. Greenlearning.ca, 2006. AAAS, 1993: 275. IPCC, 2001: 46-49.

²⁷Anderson, Mohan and Sharma discuss the importance of Carbon Cycling in the article, 2005. They point out why the Carbon-transforming processes are uniquely important. All living things are made of carbon compounds and throughout their life transform carbon by growing and storing food. They also obtain and use energy by oxidizing carbon compounds. Specifically in humans, the product of our activity, Carbon Dioxide plays several vital roles in the global climate system. It regulates global temperatures, atmospheric circulation and precipitation. For these reasons the understanding of the above process is central to understanding many environmental processes and systems in general. They also note the importance in relation to citizen's participation in environmental decision-making. Environmental issues such as Global climate change, prices and uses of fossil fuels and alternative energy sources, deforestation, soil fertility, hypoxic conditions in lakes and oceans all require an understanding of carbon-transforming processes. Lastly, carbon-transforming processes and systems relating to them exemplify big ideas in the science curriculum. This topic allows opportunities to learn key ideas and ways of reasoning from different disciplines throughout the curriculum while gaining mental skills that will be used daily in their students lives. AAAS, 1993: 74. The origin of fossil fuels is as follows. At times, environmental conditions are such that plants and marine organisms grow faster than decomposers can recycle them back to the environment. Layers of energy-rich organic material have been gradually turned into great coal beds and oil pools by the pressure of the overlying earth. By burning these fossil fuels, people are passing most of the stored energy back into the environment as heat and releasing large amounts of carbon dioxide. AAAS, 1993: 74. As is noted above, in one part of the cycle, plants remove carbon dioxide from the atmosphere during the process of photosynthesis, using the carbon to make sugars and releasing the oxygen. This process significantly affects the gaseous mix of the air and is therefore an exceptionally important component of the global climate system.

²⁸Cox, 2005. "Variability is a natural feature of the climate system. It may appear as short-term fluctuations that come and go within the span of a decade or longer-term changes that last for a century or more. Such variations are the net result of a number of factors. One of these is simply the random variability that occurs within a complex, quasi-chaotic system such as the climate system because of the almost infinite number of forces acting on it. Still, there are clear theoretical limits to this variability, and these are set by large-scale controls and feedback processes that govern the amount of energy entering and leaving the atmosphere. These include such factors as the intensity of the sun's radiation, the earth's orbit and the tilt of its axis, and the concentration of greenhouse gases in the earth's atmosphere." Francis and Hengeveld, 1998: 9. Some short-term fluctuations are the result of systematic variations within the climate system. For example, the severity of winters in western Europe tends to follow the patterns of the North Atlantic Oscillation which is an alternation in pressure differences between Iceland and the Azores. Francis and Hengeveld, 1998: 34. The most commonly discussed short term climatic fluctuations in the climate have occurred because of Sun spots and volcanic eruptions. Sun spots are minor changes in the intensity of the sun's radiation. The number of sunspots on the sun's surface increases and then decreases over a cycle that varies from 7.5 to 16 years and averages slightly more than 11 years. Francis and Hengeveld, 1998: 11. Large volcanic eruptions can put forth a powerful cooling effect on weather in many parts of the world. This occurs because of the sulphur particles blown into the stratosphere can partially block incoming sunlight for a number of years. Francis and Hengeveld, 1998: 10. Other variations can be caused by the interactions between the oceans and atmosphere such as the El Niño-Southern Oscillation (ENSO) phenomenon. This is an example of natural "internal" variability on interannual time-scales. "To distinguish anthropogenic climate changes from natural variations, it is necessary to identify the anthropogenic "signal" against the background "noise" of natural climate variability." IPCC, 2001: 25. Lastly, longer variations in the climate have occurred relatively recently and have affected people significantly during that time. The Little Ice Age happened from 100 to 500 years ago. Vikings had settled on Greenland during the wet Medieval Warm Period but were driven out by the cold Little Ice Age, Alley 2000. "The impact of this sudden change of climate was dramatic and global. Glaciers advanced rapidly in Greenland, Iceland, Scandinavia, and the Alps. The Arctic pack ice extended so far south that there are six records of Eskimos landing their kayaks in Scotland. Large tracts of land, particularly at higher latitudes and altitudes, had to be abandoned. In many years, snowfall was much heavier than recorded before or since, and the snow lay on the ground for many months longer than it does today. Many springs and summers were outstandingly cold and wet, although there was great variability between years and groups of years. Crop practices throughout Europe had to be altered to adapt to the shortened, less reliable growing season, and there were many years of death and famine. Violent storms caused massive flooding and loss of life. Some of these resulted in permanent losses of large tracts of land from the Danish, German, and Dutch coasts. The dramatic cooling was captured in the paintings of the Flemish artist Pieter Bruegel (1525–1569), who initiated a new genre by completing at least seven winter landscapes in 2 years." Reiter, 2000.

- ²⁹ AAAS, 1993: 117. Ecosystem changes that result from a change in the climate include an increase or reduction in the plant and animal species in a region, a change in the number of individuals in each population, ecosystem relationships between species. Species that have adapted to specific species are susceptible to extinction if these conditions are no longer available.
- ³⁰ Historically large changes in the climate effected people's settlements and activities. The Medieval Warm Period opened Iceland, Greenland, and North America to the Vikings, and the Little Ice Age cooling that helped drive the Vikings from Greenland, caused glaciers to advance across farms in Norway and allowed Hans Brinker to skate on the canals of Holland. Alley, 2000. Modern regions will be affected because of the reliance on climate dependent economic industries. For example, the Mediterranean is likely to become less attractive for European visitors for health reasons in the summer when temperatures increase. Research indicates around seasonal favourability of individuals suggested that a climate warming of 4 degrees C would lead to a shift in the optimal summertime climate from the traditional southern coastal resorts northwards to currently less fashionable regions. This result holds true regardless of whether the warming is associated with moderate decreases or increases of precipitation. Perry, 2004.
- ³¹ Godrej, 2001: 15. The climate changes that have occurred over the past 100 years are a result of human activity since the beginning of the industrial revolution and the large scale use of fossil fuels. There are fail-safe ways to establish that the increase of Carbon Dioxide is because of human activity. The nuclei of carbon atoms in the gas in emissions from natural and human processes are different. Naturally released carbon dioxides carbon atoms have a measurable levels of radioactivity but the nuclei of carbon from fossil fuel sources has less radioactivity because of being stored in the earth for millions of years. Godrej, 2001: 15.
- ³² Estimates suggest that terrestrial vegetation and soils take up only about 40% of global CO₂ emissions from human activities. Coward and Weaver, 2004: 92.
- ³³ Mike Hulme explores the definition of abrupt climate change in his article, *Abrupt Climate Change; can society cope?* 2003. One description is, "technically, an abrupt climate change occurs when the climate system is forced to cross some threshold, triggering a transition to a new state at a rate determined by the climate system itself and faster than the cause. The cause may be chaotic and thus undetectably small." More generally he states that, abrupt climate change depends on the rate, severity and direction of changes occurring in the global climate system. The conclusions of the IPCC studies of what changes have and are occurring are considered as benchmarks of the present rate, severity and direction of the climate changes. When these reach a certain point, the Climate Change will be considered abrupt. The possibility for rapid and irreversible changes in the climate system exists, but there is a large degree of uncertainty about the mechanisms involved and hence also about the likelihood or time-scales of such transitions. The climate system involves many processes and feedbacks that interact in complex nonlinear ways. This interaction can give rise to thresholds in the climate system that can be crossed if the system is perturbed sufficiently. There is evidence from polar ice cores suggesting that atmospheric regimes can change within a few years and that large-scale hemispheric changes can evolve as fast as a few decades. For example, the possibility of a threshold for a rapid transition of the Atlantic THC to a collapsed state has been demonstrated with a hierarchy of models. It is not yet clear what this threshold is and how likely it is that human activity would lead it to being exceeded. Atmospheric circulation can be characterised by different preferred patterns; e.g., arising from ENSO and the NAO/AO, and changes in their phase can occur rapidly. Basic theory and models suggest that climate change may be first expressed in changes in the frequency of occurrence of these patterns. Changes in vegetation, through either direct anthropogenic deforestation or those caused by global warming, could occur rapidly and could induce further climate change. It is supposed that the rapid creation of the Sahara about 5,500 years ago represents an example of such a non-linear change in land cover." IPCC, 2001: 53.
- ³⁴ Each model must use estimates of the amount of CO₂ emissions from humans. Policies and agreements, such as the Kyoto Agreement, are established so humans will reach the lower estimates of CO₂ emissions and therefore experience less Climate Change. The models being used to predict future warming still contain too much uncertainty. Although they have improved and continue to evolve, the global climate system is very complex, making it difficult to accurately account for every factor. Greenlearning.ca, 2006.
- ³⁵ Changes that are already being observed are to the rising sea levels, changes in the water cycle (precipitation increasing or decreasing in areas, ocean temperatures etc) and air temperatures (increasing and decreasing in certain areas effecting other systems such as the water cycle and oceans). Vulnerable areas to water level changes are low-lying nations and islands states, coastlines and deltas, regions already vulnerable to drought and desertification, fragile mountain ecosystems. Greenlearning.ca, 2006. Presently, the human species have major impacts on other species such as: reducing the amount of the earth's surface available to those other species, interfering with their food sources, changing the temperature and chemical composition of their habitats. These impacts are and will be increased due to human induced climate changes, AAAS, 1993: 57. Based on our current understanding of climate change science, future climate change impacts will result in: ice cap and glacier reduction, species movements and desertification. Examples of changes occurring in socio-economic systems will include: spread of disease, dealing with extreme hot

and cold weather conditions, availability and quality of water, Subsistence Hunting, Hydroelectricity, Agriculture, Forestry, Fisheries, human Health, Infrastructure & Tourism and Recreation. Greenlearning.ca, 2006. The indirect effects of climate change will alter the environment and ecosystems in which we live. These indirect effects will occur through insect- and rodent-transmitted diseases (e.g., West Nile virus fever; Lyme disease and Hantavirus Pulmonary Syndrome); increased smog and air pollution; waterborne and food-related illnesses (e.g., giardia, E. coli infection, and shellfish poisoning); and stronger UV radiation, which is a leading cause of skin cancer and. Climate change models that don't take into account any decreases in Greenhouse Gas emissions (the 'business as usual' scenario) estimate 3 billion people will see an increase in 'water stress'. Specifically those in Northern Africa, Middle East and the Indian subcontinent. Godrej, 2001: 57. Pollution Probe, 2004: 14.

- ³⁶ Canada being in the Northern Latitudes is expected to experience change greater than global averages, the IPCC estimates. Due to the size of Canada and its location on the globe it will experience Climate Change in very specific ways in specific regions and to varying degrees. Arctic and Subarctic Canada will experience the greatest temperature and precipitation changes. Coward and Weaver, 2004: 73-74. Examples of specific changes in specific regions are; In the North the depletion of Sea Ice will affect dependent animals such as Polar Bears and Seals as well as Indigenous hunters who rely heavily on these animals. Also, transportation with regard to ice roads in the winter and shipping in channels will be affected by changing water levels. These activities will affect Canadians economically and socially as well as effecting the environment. The eastern Arctic will experience more severe winter storms and human adaptation must be significant with regards to rapid changes in Northern economies and institutions. The Southern Prairie Provinces will be most affected by water changes due to climate change and therefore agriculture seriously affected. Crops are also affected by higher temperatures, as are pests that are an important factor in farming. Southern Ontario and Southwest Quebec having the Great Lakes and St. Lawrence systems will be affected by changing water levels due to higher evaporation in warmer temperatures. Water management, flash flood potential will also increase in these areas Coward and Weaver, 2004: 75-84.
- ³⁷ Climate change will impact upon people disproportionately. The actions or inaction of present generations will affect future generations. Many industrialized countries will not suffer the consequences of climate change at the same level as those from less developed nations. People in industrialized countries generate over 62 times more CO₂ pollution per person than in the least industrialized countries. Godrej, 2001: 32. Social tradeoffs are often generational. The cost of benefits received by one generation may fall on subsequent generations. Also, the cost of a social trade-off is sometimes borne by one generation although the benefits are enjoyed by their descendants. AAAS, 1993: 166. Industrialised and developing countries experience the impacts of Climate Change in very disproportionate ways. For example, 96% of all deaths from natural or unnatural disasters happen in the developing world. The spreading of disease is the primary force behind these deaths because of the substantially fewer resources, supports and infrastructure compared to industrialized countries. Godrej, 2001: 48.
- ³⁸ The increase of CO₂ in the atmosphere was first recognized in the late 1800's. Scientists, Politicians and Industries have debated and met about climate change in many historically significant speeches and conferences. Some have had a significant impact on making Climate Change an important social problem and some have created conflict and debate, many issues are still very unresolved. The following is a timeline including significant events in Climate Change history.
- 1827:** French polymath Jean-Baptiste Fourier predicts an atmospheric effect keeping the Earth warmer than it would otherwise be. He is the first to use a greenhouse analogy.
- 1863:** Irish scientist John Tyndall publishes a paper describing how water vapour can be a greenhouse gas.
- 1890s:** Swedish scientist Svante Arrhenius and an American, P C Chamberlain, independently consider the problems that might be caused by CO₂ building up in the atmosphere. Both scientists realise that the burning of fossil fuels could lead to global warming, but neither suspects the process might already have begun.
- 1890s to 1940:** Average surface air temperatures increase by about 0.25 °C. Some scientists see the American Dust Bowl as a sign of the greenhouse effect at work.
- 1940 to 1970:** Worldwide cooling of 0.2°C. Scientific interest in greenhouse effect wanes. Some climatologists predict a new ice age.
- 1957:** US oceanographer Roger Revelle warns that humanity is conducting a "large-scale geophysical experiment" on the planet by releasing greenhouse gases. Colleague David Keeling sets up first continuous monitoring of CO₂ levels in the atmosphere. Keeling soon finds a regular year-on-year rise.
- 1979:** First World Climate Conference adopts climate change as major issue and calls on governments "to foresee and prevent potential man-made changes in climate."
- 1985:** First major international conference on the greenhouse effect at Villach, Austria, warns that greenhouse gases will "in the first half of the next century, cause a rise of global mean temperature which is greater than any in man's history." This could cause sea levels to rise by up to one metre, researchers say. The conference also reports that gases other than CO₂, such as methane, ozone, CFCs and nitrous oxide, also contribute to warming.
- 1987:** Warmest year since records began. The 1980s turn out to be the hottest decade on record, with seven of the eight warmest years recorded up to 1990. Even the coldest years in the 1980s were warmer than the warmest years of the 1880s.

- 1988:** Global warming attracts worldwide headlines after scientists at Congressional hearings in Washington DC blame major US drought on its influence. Meeting of climate scientists in Toronto subsequently calls for 20% cuts in global CO₂ emissions by the year 2005. UN sets up the Intergovernmental Panel on Climate Change (IPCC) to analyse and report on scientific findings.
- 1990:** The first report of the IPCC finds that the planet has warmed by 0.5°C in the past century. IPCC warns that only strong measures to halt rising greenhouse gas emissions will prevent serious global warming. This provides scientific clout for UN negotiations for a climate convention. Negotiations begin after the UN General Assembly in December.
- 1991:** Mount Pinatubo erupts in the Philippines, throwing debris into the stratosphere that shields the Earth from solar energy, which helps interrupt the warming trend. Average temperatures drop for two years before rising again. Scientists point out that this event shows how sensitive global temperatures are to disruption.
- 1992:** Climate Change Convention, signed by 154 nations in Rio, agrees to prevent "dangerous" warming from greenhouse gases and sets initial target of reducing emissions from industrialised countries to 1990 levels by the year 2000.
- 1994:** The Alliance of Small Island States - many of whom fear they will disappear beneath the waves as sea levels rise - adopt a demand for 20% cuts in emissions by the year 2005. This, they say, will cap sea-level rise at 20 centimetres.
- 1995:** The hottest year recorded to date. In March, the Berlin Mandate is agreed by signatories at the first full meeting of the Climate Change Convention in Berlin. Industrialised nations agree on the need to negotiate real cuts in their emissions, to be concluded by the end of 1997.
- In November, the IPCC states that current warming "is unlikely to be entirely natural in origin" and that "the balance of evidence suggests a discernible human influence on global climate". Its report predicts that, under a "business as usual" scenario, global temperatures by the year 2100 will have risen by between 1°C and 3.5°C.
- 1996:** At the second meeting of the Climate Change Convention, the US agrees for the first time to legally binding emissions targets and sides with the IPCC against influential sceptical scientists. After a four-year pause, global emissions of CO₂ resume their steep climb, and scientists warn that most industrialised countries will not meet Rio agreement to stabilise emissions at 1990 levels by the year 2000.
- 1997:** Kyoto Protocol agrees legally binding emissions cuts for industrialised nations, averaging 5.4%, to be met by 2010. The meeting also adopts a series of flexibility measures, allowing countries to meet their targets partly by trading emissions permits, establishing carbon sinks such as forests to soak up emissions, and by investing in other countries. The precise rules are left for further negotiations. Meanwhile, the US government says it will not ratify the agreement unless it sees evidence of "meaningful participation" in reducing emissions from developing countries.
- 1998:** Follow-up negotiations in Buenos Aires fail to resolve disputes over the Kyoto "rule book", but agree on a deadline for resolution by the end of 2000. 1998 is the hottest year in the hottest decade of the hottest century of the millennium.
- 2000:** IPCC scientists re-assess likely future emissions and warn that, if things go badly, the world could warm by 6°C within a century. A series of major floods around the world reinforce public concerns that global warming is raising the risk of extreme weather events. But in November, crunch talks held in The Hague to finalise the "Kyoto rule book" fail to reach agreement after EU and US fall out. Decisions postponed until at least May 2001.
- 2001:** The new US president, George W Bush, renounces the Kyoto Protocol because he believes it will damage the US economy. After some hesitation, other nations agree to go ahead without him. Talks in Bonn in July and Marrakech in November finally conclude the fine print of the protocol. Analysts say that loopholes have pegged agreed cuts in emissions from rich-nation signatories to less than a third of the original Kyoto promise. Signatory nations urged to ratify the protocol in their national legislatures in time for it to come into force before the end of 2002.
- 2002:** Parliaments in the European Union, Japan and others ratify Kyoto. But the protocol's complicated rules require ratification by nations responsible for 55% of industrialised country emissions, before it can come into force. After Australia joins the US in reneging on the deal, Russia is left to make or break the treaty, but hesitates. Meanwhile, the world experiences the second hottest year on record.
- 2003:** Globally it is the third hottest year on record, but Europe experiences the hottest summer for at least 500 years, with an estimated 30,000 fatalities as a result. Researchers later conclude the heat wave is the first extreme weather event almost certainly attributable to man-made climate change. Extreme weather costs an estimated record of \$60 billion this year. 2003 also sees a marked acceleration in the rate of accumulation of greenhouse gases. Scientists are uncertain if it is a blip or a new, more ominous trend. Meanwhile Russia blows hot and cold over Kyoto.
- 2004:** A deal is struck on Kyoto. President Putin announces in May that Russia will back the Protocol - and the EU announces it will support Russia's membership of the World Trade Organization. On 18 November, the Russian parliament ratifies the protocol, paving the way for it to come into force in 2005.
- 2005:** Second warmest year on record. Researchers link warming to a record US hurricane season accelerated melting of Arctic sea ice and Siberian permafrost, and apparent disruption of the global ocean current that warms Europe. The Kyoto Protocol comes into force. In December, Kyoto signatories agree to discuss emissions targets for the second compliance period beyond 2012, while countries without targets, including the US and China, agree to a "non-binding dialogue" on their future roles in curbing emissions.

New Scientist, 2006.

- ³⁹ The original article written by Garret Hardin in 1968 addresses the tragedy of the commons concerning not climate change, but population growth. Hardin describes a situation where a pasture is open to all where each herdsman can keep as many cattle as possible on the commons. Each herdsman tries to rationalize his gain thinking, "What is the utility to me of adding one more animal to my herd?". The answer includes one negative and one positive utility. Firstly, the herdsman benefits from one additional animal and later the sale of that animal. The negative utility concerns the overgrazing of the commons created by that one animal. This does not have an equal negative impact to the herdsman compared to the positives. The herdsman shares this with others. Hardin concludes, "...Each man is locked into a system that compels him to increase his herd without limit – in a world that is limited. Ruin is the destination toward which all men rush, each pursuing his own best interests in a society that believes in the freedom of the commons. Freedom in a commons brings ruin to all." Pojman (ed.) 1997: 306. More information on the Tragedy of the Commons can be found at, en.wikipedia.org/wiki/Tragedy_of_the_commons – viewed June 27 2006. The original essay can be found on the Internet here, <http://dieoff.org/page95.htm> - viewed June 27 2006.
- ⁴⁰ The majority of the world's scientists acknowledge climate change as a phenomena that is occurring and one that will have serious repercussions. These include the International Council of Science found at www.icsu.org, National Academies of Science for Canada, United States, Britain, Germany, Italy, France, Japan, Russia, Brazil, China, India and others, the American Geophysical Union, American Meteorological Society, NASA's Goddard Institute for Space Studies, the National Oceanic and Atmospheric Administration, the Environmental Protection Agency, the US National Centre for Atmospheric Research, and the Canadian Meteorological and Oceanographic Society.
- ⁴¹ The media constructs what many citizens scientifically and politically know about Climate Change. "Our research suggests that the US, with differing industries, predominantly dominated by the fossil fuel industry, in comparison to New Zealand and Finland, has a significant impact on the media coverage of global warming. The U.S.'s media states that global warming is controversial and theoretical, yet the other two countries portray the story that is commonly found in the international scientific journals. Therefore, media acting as one driving force is providing citizens with piecemeal information that is necessary to assess the social, environmental and political conditions of the country and world." Dispensa and Brulle, 2003: 74. The dominant model of the public media is one that is characterized by "the manipulative deployment of media power to procure mass loyalty, consumer demand, and compliance with systemic imperatives." Habermas 1992:453. Dispensa and Brulle, 2003: 78. Research suggests a typical paper will reject over 75% of the daily news. This illustrates the impact they can have on what news stories get printed and what messages are sent to the viewer. Dispensa and Brulle, 2003: 80. It has also been concluded that while scientific and political forces are both important to the debate, scientists become less dominant sources as the issue matures. As this occurs, the emphasis of the news coverage concurrently shifts away from a presentation of the issue in terms of its causes and problematic nature and toward a presentation more grounded in political debate and the proposal of solutions. Trumbo, 1996: 281.
- ⁴² A number of industry groups and others who believe that action on climate change is not in their self interest use various means to prevent change. These include media and political process manipulation, attempts to discredit the science, and instilling confusion by promoting obscure scientific representatives who disagree with the majority held view in the scientific community. These actions have occurred with other issues where science has identified problems that require changes for the good of society that are contrary to the economic interests of a sector. The dairy industry initially opposed pasteurization early in the 20th century by trying to discredit the science that demonstrated that pasteurization reduced disease. Similarly the pesticide industry worked to discredit scientific findings that use caused severe problems in ecosystems. New ideas that do not mesh well with mainstream ideas in science often encounter vigorous criticism AAAS, 1993: 13.

Motivation for undermining of climate change science often relates to short-term self interest. Changes may require a reduction of the value of infrastructure and manufacturing investments, reduction in use of particular resources that businesses are focused, and other economic challenges.

Various organizations have developed significant campaigns against climate change including the Global Climate Coalition founded in 1989 by 46 corporations and trade associations representing all major elements of US industry. It funded studies on the economics of the cost of mitigating climate change, which formed the basis of their 1997/1998 multi-million dollar advertising campaign against the Kyoto Protocol. Similarly the Greening Earth Society founded on Earth Day 1998 by the Western Fuels Association to promote the view that increasing levels of atmospheric CO₂ are good for humanity.

- ⁴³ There are some methods to deal with the problem involve maximizing carbon uptake and offsetting humans excess greenhouse gas emissions. This can be done by creating Carbon stocks and sinks with forests and agriculture. Agriculture can also be used as a biofuel instead of fossil fuels. Coward and Weaver, 2004: 239. Individual actions include installing energy efficient light bulbs, replacing appliances with highest efficiency models, wash clothes in cold water, turn down your thermostat 1C, Reduce air travel, reduce consumption, become a vegetarian and buy locally produced seasonal produce. Godrej, 2001: 135. Some governments are undertaking efforts at the provincial, national and international levels to response to climate change. To various degrees, governments try to bring about social change or to impede it through policies, laws, incentives, or direct coercion. Sometimes such efforts achieve their intended results and sometimes they do not AAAS, 1993: 163. The United Nations Intergovernmental panel on Climate Change (IPCC) conducts research on Climate Change and hold conferences to bring together scientists, economists and politicians to spread knowledge and make change. Godrej, 2001: 19. International agreements such as the Kyoto accord have attempted to control the greenhouse gas emissions and bring them down to previous levels.
- ⁴³ For example, Insurance companies in industrialized countries fear that extreme weather events could bankrupt the industry and destabilize world markets. Godrej, 2001: 35. Andersson and Wallin, 2000. The growing interdependence of world social, economic, and ecological systems does not always bring greater worldwide stability and often increases the costs of conflict AAAS, 1993: 174.
- ⁴⁴ A drastic reduction in CO2 emissions would have repercussions throughout the web of dependence through its impact on the economy, business activities, infrastructure, social institutions, and the environment. The prices of implementing a carbon tax are less than formerly imagined. Globe and Mail June 19, 2006
- ⁴⁵ At present there is no economic disincentive for the user applied when carbon based fossil fuels are used. These costs (climate change, smog, resource depletion etc) are born by all people of the world, though unevenly, even though some of these people may not have enjoyed the benefits. Until the cost of using fossil fuels is borne by the users, it is unlikely that alternative energy sources will be used to the degree necessary.
- ⁴⁶ Moreover, there are two very sound reasons why we should seek global agreement on adaptation. First, our current vulnerability to existing climatic variability is very costly. For instance, about 640 million people are at risk of hunger now. Poverty is the root cause, but much of the year-to-year variability in hunger is due to drought. By drought proofing those at risk now we could secure their present livelihood and reduce the impact of future climate change. There are many kinds of such 'win-win' solutions that serve both our present and future needs, such as increasing irrigation efficiency, breeding more drought-resistant crops and developing buffer stocks of food. Second, adapting to climatic variability has a substantially greater effect of reducing impact than does mitigation. Consider, for example, the effect of reducing water demand by 5 and 10 per cent below current projections for 2050. Reducing water demand by just 5 per cent has four times as great an effect as reducing emissions by 30 per cent. Broadly, the same stress-reducing outcomes would stem from similar demand reductions in other impact sectors (such as reducing soil erosion, or reducing crop yield losses to pests and diseases). Parry et al 1998.
- ⁴⁷ Moore, 1998. Global Warming: More than Hot Air?
- ⁴⁸ An example of this attitude follows. "Since the data indicate that the small amount of warming we have detected over the last 100 years has largely been confined to winter evenings in the far northern latitudes, we have every reason -- both empirical and theoretical -- to believe that warming would be a benign, not a deleterious, event. Taylor, 1997.
- ⁴⁹ See Agence France Presse (2005).
- ⁵⁰ Representation in the news media is a fundamental part of the process of social problem definition. Climate Change has been presented with much scientism in the media. Trumbo, 1996: 269.
- ⁵¹ Smil, 2003.
- ⁵² AAAS, 1993: 275.
- ⁵³ See Agence France Presse (2005)

- ⁵⁴ Those who do not use an automobile, use renewable energy sources, operate energy efficient housing/devices, live “locally” ... Informed citizens make greater and more frequent contributions to solving the climate change problem when they gain in social reputation for doing so. Stabilizing the Earth’s Climate is not a losing game: Supporting evidence from public goods experiments. Milinski et al 2006. Findings suggest that enhancing the social reputation of people who have invested in climate change alleviating activities is a successful approach.
- ⁵⁵ For example examine the socioeconomic impacts of climate change on communities in the Mackenzie Basin in northwestern Canada.
- ⁵⁶ The cause of the seasons is a subtle combination of global and orbital geometry and of the effects of radiation at different angles. Students can learn part of the story at this grade level, but a complete picture cannot be expected until later. AAAS, 1993: 68. Developmentally, students can now consolidate their prior knowledge of the earth (as a planet) by adding more details (especially about climate), getting a firmer grasp of the geometry involved in explaining the seasons AAAS, 1993: 68.
- ⁵⁷ Anderson, Mohan and Sharma, 2005: 15. Children need to learn a new kind of explanation—one that explains by tracing matter through systems rather than narratives of how conditions or circumstances cause events. This development of understanding is essential for citizens when making environmental decisions. Anderson, Mohan and Sharma, 2005: 20
- ⁵⁸ Andersson and Wallin, 2000.
- ⁵⁹ AAAS, 1993: 67.
- ⁶⁰ Some examples of these misconceptions are: *Humid air is oppressive and heavy; humid air is more dense than dry air. Humidity is moisture in the air.* Humid air is less dense than dry air. It has more water vapor in it but that makes the air less dense - water’s molecular weight is 18, dry air’s is 29. Henriques, 2000. Many students believe that blowing on something always makes it move away. Some students believe that blowing takes the pressure with it. Blowing creates areas of faster moving air which has a lower air pressure. High pressure areas will cause motion into the areas of low pressure. Henriques, 2000.
- ⁶¹ Hengeveld, Bush and Edwards, 2002: 7.
- ⁶² Many believe that Global warming and the greenhouse effect are the same thing. Global warming is the name given to the phenomena whereby the surface of the earth gets hotter. Our planet is warmer with an atmosphere than it would be without. This phenomena has been given the name Greenhouse Effect. The atmosphere is different than a greenhouse in that it radiates energy back to Earth rather than simply trapping energy inside. Henriques, 2000.
- ⁶³ This is evidenced by the fact that students believe that recycling paper or preserving endangered species would help reduce the greenhouse effect. Students have developed an understanding that the environment is ‘good’ and whatever threatens it is ‘bad.’ This results in confusion regarding environmental issues. Additionally, the confusion as to cause and effect might be due to explaining different phenomena using the same concepts, such as gases, layers surrounding the earth and radiation from the sun. Students don’t separate ozone and warming because they are so related Meadows and Wiesenmayer, 1999: 237. Students confound the origins of one problem with the origins of others, the repercussions of one are confused with the repercussions of others, and students believe that any environmentally friendly action can help resolve any environmental problem Boyes, Chuckran and Stanisstreet, 1993: 541. For example, almost half of students in a study thought that improved protection of rare species would reduce global warming. This reveals wider confusion in the minds of students. Here, a consequence (a decrease in global biodiversity) is envisaged as a cause. The logic is inverted: we need to correct the consequence (by protecting endangered species) to correct the cause (the degradation of the species’ environment by the greenhouse effect) Boyes, Chuckran and Stanisstreet, 1993: 547, 550. Other misconceptions from students include confusing acid rain and global warming Boyes, Chuckran and Stanisstreet, 1993: 546-7, as well as, the belief that *Ozone layer depletion and global warming are associated.* 84% of students believed that a rise in global warming would produce an increase in skin cancer, which is a consequence of ozone-layer depletion. This misconception persists even at higher age and grade levels: the proportion of students maintaining this belief was similar in all age groups. Stanisstreet and Boyes, 2004. The Ozone layer problem and climate change are not related problems. The misconceptions that, *Ozone, no matter its location, is bad. Ozone, no matter its location, is good. The ozone hole is a hole in the sky.* Ozone can be beneficial or harmful, depending upon where it is located in the atmosphere. Ozone in the upper atmosphere blocks out damaging UV radiation. Ozone in the lower atmosphere (near earth’s surface) is a major constituent of smog and is considered a greenhouse gas. The ‘ozone hole’ is an area of the atmosphere where the ozone levels are lower than expected. Henriques, 2000: 236.

- ⁶⁴ *Less use of nuclear power to generate energy would reduce global warming.* Nuclear power has other problems associated with it, namely the toxicity of its waste products, their long life and the difficulty in storing them. Daniel B., Stanisstreet and Boyes, 2004.
- ⁶⁵ Some students believed that dumping garbage in rivers and polluting waters were associated with global warming. And that using unleaded gasoline and reducing the use of pesticides would contribute to diminishing global warming. Stanisstreet and Boyes, 2004. In a study of Students' understanding of actions that ameliorate the greenhouse effect the following was found: most students (87%) appreciated that tree planting could help reduce the greenhouse effect, but fewer students (68%) recognized the value of 'complementary action' such as using recycled paper to conserve trees, although awareness increased with age. Students understood that energy generation and use was linked with global warming: 68% of students realized the advantages of generating electricity from renewable sources. Some 47% of the students thought that improved protection of rare species would reduce global warming, and this misconception persisted with age. This reveals wider confusion in the minds of students as discussed above. Students appreciated the link between the use of automobiles and global warming: 83% of students realized that a reduction in automobile usage would help reduce the greenhouse effect. However, 52% of students incorrectly believed that the use of lead-free gasoline (which diminished atmospheric lead pollution) would reduce global warming, with this belief higher among older students. Boyes, Chuckran and Stanisstreet, 1993: 547, 550.
- ⁶⁶ While students understand that an increase in the greenhouse effect will cause the earth to get hotter, induce changes in global weather patterns and cause polar ice caps to melt, only half of students realize that an increase in the greenhouse effect will lead to greater desertification and other similar problems. Boyes, Chuckran and Stanisstreet, 1993: 546. Students don't realize that an increase in temperature might widen the habitual range of some temperature-limited species. Boyes, Chuckran and Stanisstreet, 1993: 546.
- ⁶⁷ AAAS, 1993: 274.
- ⁶⁸ Because the earth turns daily on an axis that is tilted, sunlight falls more intensely on different parts of the earth during the year. The difference in heating of the earth's surface produces seasons and weather patterns. AAAS, 1993: 69.
- ⁶⁹ Heat energy carried by ocean currents has a strong influence on climate around the world. AAAS, 1993: 69.
- ⁷⁰ The heat that originates from the sun emits different kinds of radiation. Certain atmospheric gases trap solar radiation after it has reached the Earth and warm it up, while some escapes back to space but some stays within the atmosphere. Koulaidis and Christidou, 1999: 569. To understand the greenhouse effect thoroughly the following scientific concepts must be understood: radiation, wavelength, the conservation of energy and steady state. Andersson and Wallin, 2000.

Global warming by the greenhouse effect is determined by the inability of the atmosphere to transmit certain wavelengths of the electromagnetic spectrum. Sunlight contains a range of wavelengths of electromagnetic radiation. When radiation is transmitted, the earth's surface heats up and begins to radiate its own electromagnetic waves. But because the earth is cooler than the sun, the wavelengths are different and thus many cannot escape through the atmosphere. Therefore, the earth heats up further and is warmer than it would be without the greenhouse effect. This warming enables life to exist on this planet and is essential to life. However, this effect has been intensified in recent decades due to an increase in greenhouse gas particles that trap the waves therefore producing the enhanced or human induced greenhouse effect. Boyes, Chuckran and Stanisstreet, 1993: 542. The name, greenhouse effect is unfortunate, for a real greenhouse does not behave as the atmosphere does. The primary mechanism keeping the air warm in a real greenhouse is the suppression of convection (the exchange of air between the inside and outside). Thus, a real greenhouse does act like a blanket to prevent bubbles of warm air from being carried away from the surface. As we have seen, this is not how the atmosphere keeps the Earth's surface warm. Indeed, the atmosphere facilitates rather than suppresses convection. Fraser, 2006. As it was discussed above, teaching material about sunlight, radiation, or environmental issues (such as ozone depletion and/or the greenhouse effect) should introduce ultraviolet radiation as a form of sunlight with special properties. Crucial ideas that might facilitate the conceptual distinction between UV and other forms of sunlight and could thus be used as facilitating conditions in teaching the greenhouse effect include 1. The conceptualization of the "sunlight" as a spectrum comprising different bands of radiation of different "character." 2. The notion that different atmospheric gases absorb electromagnetic radiation at different wavelengths. Koulaidis and Christidou, 1999: 570. Teaching the properties of sunlight wavelengths in more detail could help with students misconceptions around the relationship of Ozone Depletion, the necessary greenhouse effect and the harming enhanced greenhouse effect.

- ⁷¹ The cycling of water in and out of the atmosphere plays an important role in determining climatic patterns. Water evaporates from the surface of the earth, rises and cools, condenses into rain or snow and falls again to the surface and flows back to the ocean. AAAS, 1993: 69

- ⁷² The essential issue here is that carbon dioxide is an atmospheric component that contributes to the phenomenon of the greenhouse or atmosphere effect and that this carbon dioxide comes and goes as part of other processes on the planet's surface. Anderson, Mohan and Sharma, 2005.
- ⁷³ AAAS, 1993: 174.
- ⁷⁴ These examples of abrupt changes in atmospheric or ocean content are relatively small however they can have widespread effects on climate if the change lasts long enough. AAAS, 1993: 69.
- ⁷⁵ See endnote 70 The heat that ...
- ⁷⁶ The climate of a region affects the agriculture that can develop. Agriculture dominates the economies of most developing countries and is a significant factor in the development of any nation or society. In developing countries 70% of the population is directly dependent on agriculture for its livelihood. Also, Indigenous cultures are closely linked to the land and are intimately linked to the climate, flora fauna and landscape of their region. Natural disasters such as storms, hurricanes, tornadoes, and floods are normally relatively uncommon but when they occur they are major factors in causing social and cultural change, AAAS, 1993: 163. Climate also affects heating and cooling requirements, determines clothing and nutritional needs and limits recreational activities. Research around weather and climate show that it influences societal (e.g. civilization, culture and migration), psychological (e.g. aggression, cognition and mental illness), physiological (e.g. allergies, diet and nutrition) and economic conditions (e.g. energy production, manufacturing or labour demand). Rehdanz and Maddison, 2003. In addition to the changes mentioned above research findings around individuals happiness concludes that differential patterns of global warming along with a changed distribution of rainfall promises to alter dramatically the distribution of happiness between nations with some countries moving towards a preferred climate and others moving further away. The research found that a higher mean temperatures in the coldest month increase happiness, whereas higher mean temperatures in the hottest month decrease happiness. Rehdanz and Maddison, 2003.
- ⁷⁷ The 1992 United Nations Framework Convention on Climate Change (UNFCCC) defines "climate change" as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere. . ." United Nations Framework Convention on Climate Change, The. 2006. In contrast, the Intergovernmental Panel on Climate Change (IPCC) defines climate change more broadly and includes reference to land use change: "climate change refers to a statistically significant variation in either the mean state of the climate or in its variability. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use" IPCC, 2001. See Marland et al 2003: 150. "Global warming" refers to the rise in the Earth's temperature resulting from an increase in heat-trapping gases in the atmosphere. Union of Concerned Scientists http://www.ucsusa.org/global_warming/science/global-warming-faq.html#1 – viewed September 1 2006. For a discussion on differences between the two phenomenon see Pollution Probe, 2004: 6.
- ⁷⁸ AAAS, 1993: 69. The main contributor to climate change is fossil fuel use which releases carbon that has been stored underground for millions of years into the atmosphere at a relatively rapid rate, beyond the capacity of the climate system to absorb it. Therefore climate change occurs. The increase of Carbon Dioxide has happened because the rate at which CO₂ is being emitted from the burning of fossil fuels and deforestation (among other sources) exceeds the rate at which it is absorbed and stored on land and in oceans. Coward and Weaver, 2004. The alteration of the land cover and changes in the way land is used affect the biogeochemical cycles of the Earth, the level of atmospheric greenhouse gases, and other land surface characteristics. Coward and Weaver, 2004: 92. 61% of the anthropogenic greenhouse forcing can be attributed to CO₂ increases. During the past century (1850-1980), fossil fuels accounted for the release of 150-190PG of carbon, and land-use change accounted for the release of 90-120 PgC. With land use changes making the greater contribution prior to about 1910. At a landscape scale, changes in land-cover patterns can directly impact energy and mass fluxes. For example, when large areas of forests are cleared, reduced transpiration results in less cloud formation, less rainfall, and increased drying. Simulations of the deforestation of Amazonia indicate that evapotranspiration and forests would be replaced by either desert or pasture. Dale, 1997. With changes in land use and land cover all of the elements of climate change come into play. Changes in land surface can result in emission or removal of CO₂ to the atmosphere and thus to changes in the Earth's radiation balance. Changes in land surface can also change the radiation balance by altering the Earth's surface albedo. In addition, changes in land surface can alter the fluxes of sensible and latent heat to the atmosphere and thus the distribution of energy within the climate system; and in so doing can alter climate at the local, regional, and even global scale. Marland et al 2003: 151.
- ⁷⁹ See Syukuro and Stouffer, 1993.

- ⁸⁰ Human activities can, deliberately or inadvertently, alter the equilibrium in ecosystems. AAAS, 1993: 117. Human activities that have contributed to climate change include: releasing chemicals into the air in amounts beyond those that can be accommodated, reducing the amount of forest cover and intensive farming. AAAS, 1993: 73. Research indicates 61% of the anthropogenic greenhouse forcing can be attributed to CO₂ increases. During the past century (1850-1980), fossil fuels accounted for the release of 150-190PG of carbon, and land-use change accounted for the release of 90-120 PgC. With land use changes making the greater contribution prior to about 1910. Marland et al 2003: 151.
- ⁸¹ U.S. temperatures increased by approximately 0.6°C (1°F) over the past century, while precipitation increased by 5-10 percent. The magnitude of warming, however, has varied among different regions within the United States. Alaska, for example, has experienced an average temperature increase of 2-4°C (4-7°F) in just the past 50 years. Galbraith and Parmesan, 2004: 6. Many parts of the world have shown a decrease in the occurrence of low temperature extremes, as would be expected in a warming climate. Surprisingly, though, there has not yet been a noticeable increase in high temperature extremes. The reason appears to be related to the tendency in many regions for winter temperatures to have increased more than summer temperatures and for overnight lows to have warmed more than daytime highs. Drought, on the other hand, has become more common since the 1970s in parts of Africa as well as along the coasts of Chile and Peru and in northeastern Australia. The North American prairies also saw an increase in drought during the 1980s, although these years were not as dry as either the 1930s or the 1950s. Francis and Hengeveld, 1998: 4 & 5.
- ⁸² Sea temperatures in the tropics have increased by almost 1°C over the past 100 years and are currently increasing at the rate of approximately 1-2°C per century. Walther et al, 2002. Hoegh-Guldberg, 1999.
- ⁸³ The elements of climate change include global average surface temperature; global average sea level; the frequency, intensity, and location of extreme events; the length of the regional growing season; soil moisture; above- and below-ground biomass; local precipitation, etc. Climate change is occurring at all spatial scales from local to regional to global. Human society is currently helping to produce a global climate for which there is no precedent in the historic or prehistoric records. Marland et al 2003: 151.
- ⁸⁴ The most recent scientific evidence strongly suggests that the Arctic is experiencing warming at a rate greater than almost any other region of the globe. This is evidenced by the thickness of the ice cover; the occurrence of both the melting and freezing of the Arctic Ocean and its surrounding waterways; and from the samples of ice cores. Observations made by northern Aboriginal peoples also lend credence to the evidence that the Arctic is warming up. Insects have been reported much further north than is the norm. Changes in animal migration patterns have also been reported. Both northern Aboriginal peoples and scientists have reported significant changes in the hunting patterns of predators such as the polar bear. For example, Ian Sterling, one of the world's leading experts on the North American polar bear has noted that the polar bear population inhabiting the Hudson Bay region has become smaller. He attributes this to the earlier melting of the ice cover on Hudson Bay, which has made it more difficult for the bears to hunt seal. The Canadian Ice Services of Environment Canada has noted that the ice cover has decreased since the mid-1970s. Satellite data show that the ice cover has steadily been decreasing. Huebert, 2001: 87.
- ⁸⁵ The evidence indicates that only 30 years of warmer temperatures at the end of the twentieth century have affected the phenology of organisms, the range and distribution of species, and the composition and dynamics of communities. These examples, spanning the previous century and encompassing most major taxa and ecosystems on Earth, provide linkages between recently observed changes in natural systems and twentieth century climate change. Walther et al, 2002: 394. A climate "fingerprint" is discernible in natural systems. The most rigorous studies within the United States provide strong evidence that climate change has affected the timing of biological events in at least three taxa (i.e., groups of related species). They also provide strong evidence that at least three taxa have shifted their ranges in response to climate change and that climate change has altered ecological communities and processes. Further, very few instances of biotic change run completely counter to climate-change predictions, and the findings of many of the U.S. studies are mirrored by studies elsewhere around the world. Galbraith and Parmesan, 2004. Common changes in the timing of spring activities include earlier breeding or first singing of birds, earlier arrival of migrant birds, earlier appearance of butterflies, earlier choruses and spawning in amphibians and earlier shooting and flowering of plants. In general, spring activities have occurred progressively earlier since the 1960s. Walther et al, 2002.
- ⁸⁶ The Alaskan tundra has switched from being a net sink of CO₂ (absorbing and storing more carbon from the atmosphere than is released) to being a net source of CO₂ (releasing more carbon than is stored), because warmer winters have allowed dead plant matter previously stored in the soil to decompose and release CO₂. Like the tundra, boreal forests have become carbon sources because of reduced growth due to climate-mediated increases in water stress, pest outbreaks, and wildfires. Conversely, many of the forests of the lower 48 states have switched in the opposite direction—becoming carbon sinks in recent decades. This transition is attributed to regrowth of forests following logging and abandonment of agricultural fields. However, it is expected to stop as soon as

the forests mature. Galbraith and Parmesan, 2004: iv. In Antarctic terrestrial ecosystems, visually dramatic examples of biological changes in response to climatic warming include the colonization by macroscopic plants (largely mosses) of previously bare or newly exposed ground and the rapid expansion in extent and numbers of the only two higher plants present on the continent. Walther et al, 2002: 392.

- ⁸⁷ With general warming trends, these 'climate envelopes' become shifted towards the poles or higher altitudes. To the extent that dispersal and resource availability allow, species are expected to track the shifting climate and likewise shift their distributions poleward in latitude and upward in elevation. Walther et al, 2002: 392.
- ⁸⁸ Poised near their upper thermal limits, coral reefs have undergone global mass bleaching events whenever sea temperatures have exceeded long-term summer averages by more than 1.0 8C for several weeks. Reef-building corals, which are central to healthy coral reefs, are currently living close to their thermal maxima. They become stressed if exposed to small slight increases (1-2oC) in water temperature and experience coral bleaching. Coral bleaching occurs when the photosynthetic symbionts of corals (zooxanthellae) become increasingly vulnerable to damage by light. Six periods of mass coral bleaching have occurred since 1979 and the incidence of mass coral bleaching is increasing in both frequency and intensity. The most severe period occurred in 1998, in which an estimated 16% of the world's reef-building corals died. See Walther et al, 2002: 392 and Hoegh-Guldberg, 1999 for more detailed descriptions.
- ⁸⁹ Food security presents a particularly worrisome problem, given the continuing growth of the world's population and the leveling off in production of key foodstuffs such as wheat and rice. Increased crop damage from droughts, floods, and storms could make famines not only more frequent but far more difficult to deal with. See Francis and Hengeveld, 1998: 26.
- ⁹⁰ The Inuvialuit Community in Sachs Harbour, reported commonplace and cumulative changes that threaten their cultural future: melting permafrost resulting in beach slumping; increased snowfalls; longer sea ice-free seasons; new species of birds and fish (barn owls, mallard and pin-tailed ducks and salmon) near the community; a decline in the lemming population, the basic food for Arctic fox, a valuable harvested species; and generally a warming trend. See Fenge, 2001: 82.
- ⁹¹ Climate-linked invasions might also involve the immigration of unwanted neighbours such as epidemic diseases. There is much evidence that a steady rise in annual temperatures has been associated with expanding mosquito-borne diseases in the highlands of Asia, East Africa and Latin America. Overall, trends of range changes show remarkable internal consistency between studies relating to glaciers, plant and insect ranges and shifting isotherms. See Walther et al, 2002 and Pollution Probe, 2004.
- ⁹² See Harrison and Whittington, 1998.
- ⁹³ See Pollution Probe, 2004.
- ⁹⁴ The Earth's climate system has demonstrably changed on both global and regional scales since the pre-industrial era, with some of these changes attributable to human activities. Human activities have increased the atmospheric concentrations of greenhouse gases and aerosols since the pre-industrial era. The atmospheric concentrations of key anthropogenic greenhouse gases (i.e., carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), and tropospheric ozone (O₃)) reached their highest recorded levels in the 1990s, primarily due to the combustion of fossil fuels, agriculture, and land-use changes. The radiative forcing from anthropogenic greenhouse gases is positive with a small uncertainty range; that from the direct aerosol effects is negative and smaller; whereas the negative forcing from the indirect effects of aerosols on clouds might be large but is not well quantified. See IPCC, 2001.
- ⁹⁵ The debate can be seen clearly in Toulin's Article in the National Post titled Canada: Kyoto Possible without hurting economy: CEO's, 2002. Business leaders believe implementing the Kyoto Protocol on climate change can be achieved without causing major economic disruption, says a Financial Post poll. Some 57% of the executives said greenhouse emissions could be cut drastically with little economic impact -- the same position expressed by David Anderson, the Minister of the Environment at this time. Meanwhile, 29% of respondents said they were firmly opposed to the Kyoto Protocol and 13% had no opinion. Steve Kiar, a COMPAS senior partner, said the poll response is surprising because such key business groups as the Canadian Chamber of Commerce, the Canadian Manufacturers and Exporters and the Canadian Association of Petroleum Producers have warned that implementing the treaty would be devastating for the Canadian economy. In February (2002), the Canadian Manufacturers and Exporters said Kyoto would wipe out 450,000 manufacturing jobs in Canada, and that it would cost the economy up to \$40-billion and force a radical lifestyle change on people. Toulin, 2002.

For a skeptics article see also Moore, 1998, Warmer Earth Might be a Welcome Trend. An excerpt supposedly from a Wall Street Journal Article written by Pete Du Pont, the former governor of Delaware stated, "So what is the reality about global warming and its impact on the world? A new

study released this week by the National Center for Policy Analysis, "Climate Science: Climate Change and Its Impacts"⁹⁶ looks at a wide variety of climate matters, from global warming and hurricanes to rain and drought, sea levels, arctic temperatures and solar radiation. It concludes that "the science does not support claims of drastic increases in global temperatures over the 21st century, nor does it support claims of human influence on weather events and other secondary effects of climate change." "The environmental pessimists tell us, as in Time magazine's recent global warming issue, to "Be Worried. Be Very Worried," but the truth is that our environmental progress has been substantially improving, and we should be very pleased." Du Pont, 2006.

⁹⁶ Scientists are linked to other scientists worldwide both personally and through international scientific organizations. AAAS, 1993: 177.

⁹⁷ The global environment is affected by national policies and practices relating to energy use, waste disposal, ecological management, manufacturing, and population. AAAS, 1993: 177.

⁹⁸ See endnote 77 for Global Warming and Climate Change definitions.

⁹⁹ Extreme weather, in the most obvious sense, is weather that lies outside a locale's normal range of weather intensity. It is therefore, by definition, infrequent or rare. Extreme weather is also potentially destructive, although not all extreme weather events end in disasters. For some weather events, the idea of what constitutes an extreme can vary from place to place. It often depends on what a region is used to experiencing and what it is prepared for. A 20-cm snowfall would be an extreme event for Washington, D.C., for example, but not for Montreal. In Washington such an event would come close to an emergency. In Montreal it would be merely an inconvenience. See Francis and Hengeveld, 1998: 2.

¹⁰⁰ Studies have shown that in students' minds, the most effective ways of decreasing global warming are to reduce factory and vehicle emissions. In some respects, such actions are outside the locus of control of individual school students, who might envisage them as someone else's responsibility, with any contribution that individuals can make being insignificant. In view of this, it might be useful to encourage students towards the view that seemingly small actions can be significant, especially if made by many people. Discussing the impact of many individuals buying SUVs, with higher allowable emissions, then regular cars, can do this. Due to this increase, the technological advances in fuel emissions have had little to no positive impact on the environment. In a complementary manner, it might be useful to explore with students the link between industrial emissions and lifestyle issues. For example, although a proportion of carbon dioxide emissions are from private vehicle use and energy production for domestic use, the majority are sourced from the production of consumer goods and the provision of public services, many of which are used by young people. By a combination of these means, it might be possible to encourage students to take some "ownership" of the problem of global warming, demonstrating that they have both the ability and responsibility to contribute to its reduction. See Daniel, Stanisstreet and Boyes, 2004.

¹⁰¹ One common aspect of all social tradeoffs pits personal benefit and the rights of the individual, on one side, against the social good and the rights of society, on the other. AAAS, 1993: 166.

¹⁰² A suggestion would be to start the subject area of the greenhouse effect and greenhouses where plants are grown, by allowing small groups to discuss and work out a description of what happens in each circumstance and then to report this to the whole class. The task is reasonable as this effect is a subject of discussion and comments in the media and their understandings of heat. One may expect at least some of the models that appear in the groups' reports to be realistic. Students can then use a venn diagram to show what happens in each situation and what are the similarities and differences. Students should explore what the differences are between the glass of a greenhouse and the earth's atmosphere. Why does radiation get through in one direction but not in the opposite? Provide students with examples of small greenhouses and diagrams of how the greenhouse effect works. Activities such as this correspond with present research around using students' ideas and misconceptions to learn about an idea. Students come with strong ideas about the relationships between the greenhouse effect and greenhouses themselves and their ideas will not be changed unless they are convinced that their present mental model does not make sense. During this activity exploration and discussion of the models should be encouraged. See Andersson and Wallin, 2000.

¹⁰³ AAAS, 1993: 68.

¹⁰⁴ AAAS, 1993: 336.

¹⁰⁵ Students at this age understand the globe represents the earth. AAAS, 1993: 268. See also, Harvard-Smithsonian Center for Astrophysics: High Energy Astrophysics Division, 2006.

¹⁰⁶Examples of Cloud Misconceptions from Children are: *Clouds foretell rain*. Clouds are necessary but not sufficient predictors of rain. The presence of clouds does not mean it will rain. *Clouds (and rain) are made by God, Clouds come from somewhere above the sky, Clouds are water vapor*. A visible cloud is primarily tiny water droplets and/or tiny ice crystals; it is not water vapor. *Clouds go to the sea and get filled with water*. Students with this idea view the water cycle only in terms of liquid water - there is no phase change required for this model. The next stage is for students to view the water cycle in terms of water boiling - for students in this stage the only way water becomes a gas is through boiling (i.e., no evaporation). Clouds are created when water vapor condenses onto dust or other particles in the air. The water vapor is in the atmosphere as a result of evaporation of water from the surface of the earth, and from respiration of plants and animals. Airborne particles affect cloud formation. Henriques, 2000.

¹⁰⁷ Some examples of misconceptions of rain are: *Rain occurs because we need it, Rain occurs when clouds collide, Rain occurs when clouds become too heavy*. Rain occurs whether or not we want/need it to. When the water droplets are sufficiently heavy they fall from the clouds. Henriques, 2000.

¹⁰⁸ When closer to a heat source, one notices an increase in temperature – this means that the Earth must be closer to the sun when it is hotter. Henriques, 2002: 214. There is a slight change in the Earth's distance from the sun however this makes only a very minor effect on the seasons. See Bad Astronomy, 2006.

¹⁰⁹ The snow and ice result from cold temperatures; they are not the cause of them Henriques, 2002: 215.

¹¹⁰ Students are to distinguish between weather and climate and know, among other things, how climate influences commerce, choice of habitat and trade. Henriques, 2000.

Weather and climate phenomena occur in steady, repetitive, or irregular ways-or sometimes in more than one way at the same time. The type of change that is occurring can be determined by recording observations/measurements in a table or graph. AAAS, 1993: 273.

¹¹¹Examples of landforms that affect the weather of an area are flatlands and mountains.

¹¹²Plants can change the local conditions and affect the influence of changes due to pollution, car exhaust etc.

¹¹³ AAAS, 1993:67 .

¹¹⁴For any particular environment, some kinds of plants and animals survive well, some survive less well, and some cannot survive at all. AAAS, 1993: 116. Climate affects the day to day activities and health of every living thing on earth, especially humans.

¹¹⁵ We plan on similar weather changes throughout the year. We are dependent on stable climate and weather. AAAS, 1993: 184.

¹¹⁶ See the website Postcard Connecting Worldwide: <http://www.genevaschools.org/austinbg/class/gray/internet/electronic/index.htm> - viewed June 15 2006.

¹¹⁷ The level of math acquired by this age lets us talk about our experiences in the language of geometry (shapes, lines and angles) and numbers. See Harvard-Smithsonian Center for Astrophysics: High Energy Astrophysics Division, 2006.

¹¹⁸ AAAS, 1993: 67.

¹¹⁹ Record daily weather conditions using instruments such as thermometers, rain gauges, and wind direction indicators, and compare this record with an equivalent record produced earlier.

¹²⁰ Students need extensive experiences with both living systems and with matter. At this level these experiences can focus on visible changes—life cycles, death and decay, physical changes in solids and liquids.

Anderson, Mohan and Sharma, 2005: 15.

¹²¹ Familiarity with the modeling will help them take their observations back into the classroom with their mental gears already searching for ways to talk about what they've seen in the different arenas of experience. See Harvard-Smithsonian Center for Astrophysics: High Energy Astrophysics Division, 2006.

¹²² This activity will allow the children to begin to think about the movement of either the Sun or the Earth as well as the shape of the Earth so that motions make sense. This activity works with children's natural wonder about the world around them. Many basic questions are asked of the students about the sun and a day. They should try drawing a picture of a day to help with their ideas before this activity. When outside the teacher can draw the view ahead of them and ask if it's correct. Continue with this noting things like shadows and where they are, the sun and how high it is. Begin this in the morning and continue the activity throughout the day trying to find some patterns. See the following website for Developmental Notes, Teacher Instructional Notes, And the Inquiry Learning Activity itself.

Harvard-Smithsonian Center for Astrophysics: High Energy Astrophysics Division, 2006.

¹²³ AAAS, 1993: 67 & 262.

¹²⁴ AAAS, 1993: 67.

¹²⁵ AAAS, 1993: 262.

¹²⁶ See Harvard-Smithsonian Center for Astrophysics: High Energy Astrophysics Division, 2006.

¹²⁷ For example, when observing the sun in the sky moving throughout the day some children may believe that the sun is moving around the earth. Clouds seem to move with us when we walk. These ideas should be challenged and discussed at this age. Children should be questioned to look at other possible explanations. Any direct teaching of the complex systems or cycles they are involved in should be avoided.

¹²⁸ Many believe that Clouds move when we move. We walk and the clouds move with us., Clouds move when wind blows them, Clouds and rain are independent and Clouds foretell rain. Children see clouds from their perspective and make connections between clouds and rain. Clouds are necessary but not sufficient predictors of rain. The presence of clouds does not mean it will rain. Henriques, 2002: 211.

¹²⁹ Examples of children's' misconceptions around rain are: *Rain comes from holes in clouds (like salt from a salt shaker), Rain comes from clouds sweating, Rain comes from clouds melting, Rain falls from funnels in the clouds, Rain occurs because we need it , Rain occurs when clouds get scrambled and melt, Rain occurs when clouds are shaken by the wind, Rain occurs when clouds collide , Rain occurs when clouds become too heavy , Rain occurs whether or not we want/need it. When the water droplets are sufficiently heavy they fall from the clouds* In reality, rain begins to fall when water drops in the cloud are too heavy to remain airborne. Henriques, 2002: 211.

¹³⁰ AAAS, 1993: 67, 162, 272

¹³¹ AAAS, 1993: 83.

¹³² For example, some animals hibernate. During the winter, the temperature is cold, and food is scarce, so animals take a long nap. Since they can't eat during hibernation, animals (like the black bear) get energy from stored body fat. To prepare for this long time without food, a black bear will eat a lot during the fall, gaining about 30 pounds each week. This weight has to last for up to 100 days of hibernating. See Bryner, 2005: 43. People grow food, go on holiday and play different sports during different times of the year and trees loose their leaves in the fall and most plants grow in the spring and summer.

¹³³ See Harvard-Smithsonian Center for Astrophysics: High Energy Astrophysics Division, 2006.

¹³⁴ AAAS, 1993: 67.

¹³⁵ For example, sunscreen, hats and sunglasses, In the fall, wind jackets and boots; In the winter, long johns, thick jackets and mittens, In the spring, rain/mud boots and umbrellas

¹³⁶ See Harvard-Smithsonian Center for Astrophysics: High Energy Astrophysics Division, 2006.

¹³⁷ AAAS, 1993: 67, 162, 272

¹³⁸ Students are to distinguish between weather and climate and know, among other things, how climate influences commerce, choice of habitat and trade. Henriques, 2000.

Weather and climate phenomena occur in steady, repetitive, or irregular ways-or sometimes in more than one way at the same time. The type of change that is occurring can be determined by recording observations/measurements in a table or graph. AAAS, 1993: 273.

¹³⁹Plants can change the local conditions and affect the influence of changes due to pollution, car exhaust etc.

¹⁴⁰ AAAS, 1993: 274.

¹⁴¹Examples of landforms that affect the weather of an area are flatlands and mountains.

¹⁴² Because the Earth turns daily on an axis that is tilted, sunlight falls more intensely on different parts of the Earth during the year. The difference in heating of the Earth's surface produces seasons and weather patterns. AAAS, 1993: 69.

¹⁴³ Heat energy carried by ocean currents has a strong influence on climate around the world. AAAS, 1993: 69.

¹⁴⁴ The heat that originates from the sun emits different kinds of radiation. Certain atmospheric gases trap solar radiation after it has reached the Earth and warm it up, while some escapes back to space but some stays within the atmosphere. Koulaïdis and Christidou, 1999: 569. To understand the greenhouse effect thoroughly the following scientific concepts must be understood: radiation, wavelength, the conservation of energy and steady state. Andersson and Wallin, 2000.

Global warming by the greenhouse effect is determined by the inability of the atmosphere to transmit certain wavelengths of the electromagnetic spectrum. Sunlight contains a range of wavelengths of electromagnetic radiation. When radiation is transmitted, the Earth's surface heats up and begins to radiate its own electromagnetic waves. But because the Earth is cooler than the sun, the wavelengths are different and thus many cannot escape through the atmosphere. Therefore, the Earth heats up further and is warmer than it would be without the greenhouse effect. This warming enables life to exist on this planet and is essential to life. However, this effect has been intensified in recent decades due to an increase in greenhouse gas particles that trap the waves therefore producing the enhanced or human induced greenhouse effect. Boyes, Chuckran and Stanisstreet, 1993: 542. The name, greenhouse effect is unfortunate, for a real greenhouse does not behave as the atmosphere does. The primary mechanism keeping the air warm in a real greenhouse is the suppression of convection (the exchange of air between the inside and outside). Thus, a real greenhouse does act like a blanket to prevent bubbles of warm air from being carried away from the surface. As we have seen, this is not how the atmosphere keeps the Earth's surface warm. Indeed, the atmosphere facilitates rather than suppresses convection. Fraser, 2006. As it was discussed above, teaching material about sunlight, radiation, or environmental issues (such as ozone depletion and/or the greenhouse effect) should introduce ultraviolet radiation as a form of sunlight with special properties. Crucial ideas that might facilitate the conceptual distinction between UV and other forms of sunlight and could thus be used as facilitating conditions in teaching the greenhouse effect include, 1. The conceptualization of the "sunlight" as a spectrum comprising different bands of radiation of different "character." 2. The notion that different atmospheric gases absorb electromagnetic radiation at different wavelengths. Koulaïdis and Christidou, 1999: 570. Teaching the properties of sunlight wavelengths in more detail could help with students' misconceptions around the relationship of Ozone Depletion, the necessary greenhouse effect and the harming enhanced greenhouse effect.

¹⁴⁵The cycling of water in and out of the atmosphere plays an important role in determining climatic patterns. Water evaporates from the surface of the Earth, rises and cools, condenses into rain or snow and falls again to the surface and flows back to the ocean. AAAS, 1993: 69

¹⁴⁶ The essential issue here is that carbon dioxide is an atmospheric component that contributes to the phenomenon of the greenhouse or atmosphere effect and that this carbon dioxide comes and goes as part of other processes on the planet's surface. Anderson, Mohan and Sharma, 2005.

¹⁴⁷ The global climate weather system can best be understood through systems analysis. It has boundaries and subsystems, relationships to other systems, and inputs and outputs. AAAS, 1993: 266.

- ¹⁴⁸AAAS, 1993: 266. Positive feedbacks are mechanisms that amplify an effect and negative feedbacks can moderate an effect. Examples of some Feedback Mechanisms involved in Climate Change are: Positive feedback: A warmer atmosphere is expected to contain more water vapour, which is a greenhouse gas, thereby reinforcing the warming. Forest dieback and reduced growth due to stress caused by climate change such as increased temperatures, results in less CO₂ being taken from atmosphere. A possible negative feedback would be that due to higher concentrations of CO₂ in the atmosphere would result in an increased growth in some plants. The IPCC future climate change models predict that the net effect of land and ocean climate feedbacks as indicated is to further increase projected atmospheric CO₂ concentrations, by reducing both the ocean and land uptake of CO₂. AAAS, 1993: 275. IPCC, 2001: 46-49.
- ¹⁴⁹“Variability is a natural feature of the climate system. It may appear as short-term fluctuations that come and go within the span of a decade or longer-term changes that last for a century or more. Such variations are the net result of a number of factors. One of these is simply the random variability that occurs within a complex, quasi-chaotic system such as the climate system because of the almost infinite number of forces acting on it. Still, there are clear theoretical limits to this variability, and these are set by large-scale controls and feedback processes that govern the amount of energy entering and leaving the atmosphere. These include such factors as the intensity of the sun’s radiation, the Earth’s orbit and the tilt of its axis, and the concentration of greenhouse gases in the Earth’s atmosphere.” Francis and Hengeveld, 1998: 9. Some short-term fluctuations are the result of systematic variations within the climate system. For example, the severity of winters in Western Europe tends to follow the patterns of the North Atlantic Oscillation which is an alternation in pressure differences between Iceland and the Azores. Francis and Hengeveld, 1998: 34. The most commonly discussed short term climatic fluctuations in the climate have occurred because of Sun spots and volcanic eruptions. Sun spots are minor changes in the intensity of the sun’s radiation. The number of sunspots on the sun’s surface increases and then decreases over a cycle that varies from 7.5 to 16 years and averages slightly more than 11 years. Francis and Hengeveld, 1998: 11. Large volcanic eruptions can put forth a powerful cooling effect on weather in many parts of the world. This occurs because of the sulphur particles blown into the stratosphere can partially block incoming sunlight for a number of years. Francis and Hengeveld, 1998: 10. Other variations can be caused by the interactions between the oceans and atmosphere such as the El Niño-Southern Oscillation (ENSO) phenomenon. This is an example of natural “internal” variability on interannual time-scales. “To distinguish anthropogenic climate changes from natural variations, it is necessary to identify the anthropogenic “signal” against the background “noise” of natural climate variability.” IPCC, 2001: 25. Lastly, longer variations in the climate have occurred relatively recently and have affected people significantly during that time. The Little Ice Age happened from 100 to 500 years ago. Vikings had settled on Greenland during the wet Medieval Warm Period but were driven out by the cold Little Ice Age, Alley 2000. “The impact of this sudden change of climate was dramatic and global. Glaciers advanced rapidly in Greenland, Iceland, Scandinavia, and the Alps. The Arctic pack ice extended so far south that there are six records of Eskimos landing their kayaks in Scotland. Large tracts of land, particularly at higher latitudes and altitudes, had to be abandoned. In many years, snowfall was much heavier than recorded before or since, and the snow lay on the ground for many months longer than it does today. Many springs and summers were outstandingly cold and wet, although there was great variability between years and groups of years. Crop practices throughout Europe had to be altered to adapt to the shortened, less reliable growing season, and there were many years of death and famine. Violent storms caused massive flooding and loss of life. Some of these resulted in permanent losses of large tracts of land from the Danish, German, and Dutch coasts. The dramatic cooling was captured in the paintings of the Flemish artist Pieter Bruegel (1525–1569), who initiated a new genre by completing at least seven winter landscapes in 2 years.” Reiter, 2000.
- ¹⁵⁰Anderson, Mohan and Sharma discuss the importance of Carbon Cycling in the article, 2005. They point out why the Carbon-transforming processes are uniquely important. All living things are made of carbon compounds and throughout their life transform carbon by growing and storing food. They also obtain and use energy by oxidizing carbon compounds. Specifically in humans, the product of our activity, Carbon Dioxide plays several vital roles in the global climate system. It regulates global temperatures, atmospheric circulation and precipitation. For these reasons the understanding of the above process is central to understanding many environmental processes and systems in general. They also note the importance in relation to citizen’s participation in environmental decision-making. Environmental issues such as Global climate change, prices and uses of fossil fuels and alternative energy sources, deforestation, soil fertility, hypoxic conditions in lakes and oceans all require an understanding of carbon-transforming processes. Lastly, carbon-transforming processes and systems relating to them exemplify big ideas in the science curriculum. This topic allows opportunities to learn key ideas and ways of reasoning from different disciplines throughout the curriculum while gaining mental skills that will be used daily in their students’ lives. AAAS, 1993: 74. The origin of fossil fuels is as follows. At times, environmental conditions are such that plants and marine organisms grow faster than decomposers can recycle them back to the environment. Layers of energy-rich organic material have been gradually turned into great coal beds and oil pools by the pressure of the overlying Earth. By burning these fossil fuels, people are passing most of the stored energy back into the environment as heat and releasing large amounts of carbon dioxide. AAAS, 1993: 74. As is noted above, in one part of the cycle, plants remove carbon dioxide from the atmosphere during the process of photosynthesis, using the carbon to make sugars and releasing the oxygen. This process significantly affects the gaseous mix of the air and is therefore an exceptionally important component of the global climate system.

¹⁵¹ AAAS, 1993: 83.

¹⁵² Solar radiation heats the land masses, oceans, and air. Transfer of heat energy at the boundaries between the atmosphere, the land masses, and the oceans results in layers of different temperatures and densities in both the ocean and atmosphere. The action of gravitational force on regions of different densities causes them to rise or fall – and such circulation, influenced by the rotation of the Earth, produces winds and ocean currents.” AAAS, 1993: 70.

¹⁵³ AAAS, 1993:67 .

¹⁵⁴ AAAS, 1993: 174.

¹⁵⁵ These examples of abrupt changes in atmospheric or ocean content are relatively small however they can have widespread effects on climate if the change lasts long enough. AAAS, 1993: 69.

¹⁵⁶The 1992 United Nations Framework Convention on Climate Change (UNFCCC) defines “climate change” as “a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere. . . .” United Nations Framework Convention on Climate Change, The. 2006. In contrast, the Intergovernmental Panel on Climate Change (IPCC) defines climate change more broadly and includes reference to land use change: “climate change refers to a statistically significant variation in either the mean state of the climate or in its variability. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use” IPCC, 2001. See Marland et al 2003: 150. “Global warming” refers to the rise in the Earth’s temperature resulting from an increase in heat-trapping gases in the atmosphere. Union of Concerned Scientists http://www.ucsusa.org/global_warming/science/global-warming-faq.html#1 – viewed September 1 2006. For a discussion on differences between the two phenomena see Pollution Probe, 2004: 6.

¹⁵⁷ AAAS, 1993: 69. The main contributor to climate change is fossil fuel use which releases carbon that has been stored underground for millions of years into the atmosphere at a relatively rapid rate, beyond the capacity of the climate system to absorb it. Therefore climate change occurs. The increase of Carbon Dioxide has happened because the rate at which CO₂ is being emitted from the burning of fossil fuels and deforestation (among other sources) exceeds the rate at which it is absorbed and stored on land and in oceans. Coward and Weaver, 2004. The alteration of the land cover and changes in the way land is used affect the biogeochemical cycles of the Earth, the level of atmospheric greenhouse gases, and other land surface characteristics. Coward and Weaver, 2004: 92. 61% of the anthropogenic greenhouse forcing can be attributed to CO₂ increases. During the past century (1850-1980), fossil fuels accounted for the release of 150-190PG of carbon, and land-use change accounted for the release of 90-120 PgC. With land use changes making the greater contribution prior to about 1910. At a landscape scale, changes in land-cover patterns can directly impact energy and mass fluxes. For example, when large areas of forests are cleared, reduced transpiration results in less cloud formation, less rainfall, and increased drying. Simulations of the deforestation of Amazonia indicate that evapotranspiration and forests would be replaced by either desert or pasture. Dale, 1997. With changes in land use and land cover all of the elements of climate change come into play. Changes in land surface can result in emission or removal of CO₂ to the atmosphere and thus to changes in the Earth’s radiation balance. Changes in land surface can also change the radiation balance by altering the Earth’s surface albedo. In addition, changes in land surface can alter the fluxes of sensible and latent heat to the atmosphere and thus the distribution of energy within the climate system; and in so doing can alter climate at the local, regional, and even global scale. Marland et al 2003: 151.

¹⁵⁸ Human activities can, deliberately or inadvertently, alter the equilibrium in ecosystems. AAAS, 1993: 117. Human activities that have contributed to climate change include: releasing chemicals into the air in amounts beyond those that can be accommodated, reducing the amount of forest cover and intensive farming. AAAS, 1993: 73. Research indicates 61% of the anthropogenic greenhouse forcing can be attributed to CO₂ increases. During the past century (1850-1980), fossil fuels accounted for the release of 150-190PG of carbon, and land-use change accounted for the release of 90-120 PgC. With land use changes making the greater contribution prior to about 1910. Marland et al 2003: 151.

¹⁵⁹ See Syukuro and Stouffer, 1993.

¹⁶⁰ Godrej, 2001: 15. The climate changes that have occurred over the past 100 years are a result of human activity since the beginning of the industrial revolution and the large scale use of fossil fuels. There are fail-safe ways to establish that the increase of Carbon Dioxide is because of human activity. The nuclei of carbon atoms in the gas in emissions from natural and human processes are different. Naturally released carbon dioxides carbon atoms have a measurable levels of radioactivity but the nuclei of carbon from fossil fuel sources has less radioactivity because of being stored in the Earth for millions of years. Godrej, 2001: 15.

- ¹⁶¹ Estimates suggest that terrestrial vegetation and soils take up only about 40% of global CO₂ emissions from human activities. Coward and Weaver, 2004: 92.
- ¹⁶² Mike Hulme explores the definition of abrupt climate change in his article, *Abrupt Climate Change; can society cope?* 2003. One description is, "technically, an abrupt climate change occurs when the climate system is forced to cross some threshold, triggering a transition to a new state at a rate determined by the climate system itself and faster than the cause. The cause may be chaotic and thus undetectably small." More generally he states that, abrupt climate change depends on the rate, severity and direction of changes occurring in the global climate system. The conclusions of the IPCC studies of what changes have and are occurring are considered as benchmarks of the present rate, severity and direction of the climate changes. When these reach a certain point, the Climate Change will be considered abrupt. The possibility for rapid and irreversible changes in the climate system exists, but there is a large degree of uncertainty about the mechanisms involved and hence also about the likelihood or time-scales of such transitions. The climate system involves many processes and feedbacks that interact in complex nonlinear ways. This interaction can give rise to thresholds in the climate system that can be crossed if the system is perturbed sufficiently. There is evidence from polar ice cores suggesting that atmospheric regimes can change within a few years and that large-scale hemispheric change can evolve as fast as a few decades. For example, the possibility of a threshold for a rapid transition of the Atlantic THC to a collapsed state has been demonstrated with a hierarchy of models. It is not yet clear what this threshold is and how likely it is that human activity would lead it to being exceeded. Atmospheric circulation can be characterised by different preferred patterns; e.g., arising from ENSO and the NAO/AO, and changes in their phase can occur rapidly. Basic theory and models suggest that climate change may be first expressed in changes in the frequency of occurrence of these patterns. Changes in vegetation, through either direct anthropogenic deforestation or those caused by global warming, could occur rapidly and could induce further climate change. It is supposed that the rapid creation of the Sahara about 5,500 years ago represents an example of such a non-linear change in land cover." IPCC, 2001: 53.
- ¹⁶³ U.S. temperatures increased by approximately 0.6°C (1°F) over the past century, while precipitation increased by 5-10 percent. The magnitude of warming, however, has varied among different regions within the United States. Alaska, for example, has experienced an average temperature increase of 2-4°C (4-7°F) in just the past 50 years. Galbraith and Parmesan, 2004: 6. Many parts of the world have shown a decrease in the occurrence of low temperature extremes, as would be expected in a warming climate. Surprisingly, though, there has not yet been a noticeable increase in high temperature extremes. The reason appears to be related to the tendency in many regions for winter temperatures to have increased more than summer temperatures and for overnight lows to have warmed more than daytime highs. Drought, on the other hand, has become more common since the 1970s in parts of Africa as well as along the coasts of Chile and Peru and in northeastern Australia. The North American prairies also saw an increase in drought during the 1980s, although these years were not as dry as either the 1930s or the 1950s. Francis and Hengeveld, 1998: 4 & 5.
- ¹⁶⁴ Sea temperatures in the tropics have increased by almost 1°C over the past 100 years and are currently increasing at the rate of approximately 1-2°C per century. Walther et al, 2002. Hoegh-Guldberg, 1999.
- ¹⁶⁵ The elements of climate change include global average surface temperature; global average sea level; the frequency, intensity, and location of extreme events; the length of the regional growing season; soil moisture; above- and below-ground biomass; local precipitation, etc. Climate change is occurring at all spatial scales from local to regional to global. Human society is currently helping to produce a global climate for which there is no precedent in the historic or prehistoric records. Marland et al 2003: 151.
- ¹⁶⁶ The most recent scientific evidence strongly suggests that the Arctic is experiencing warming at a rate greater than almost any other region of the globe. This is evidenced by the thickness of the ice cover; the occurrence of both the melting and freezing of the Arctic Ocean and its surrounding waterways; and from the samples of ice cores. Observations made by northern Aboriginal peoples also lend credence to the evidence that the Arctic is warming up. Insects have been reported much further north than is the norm. Changes in animal migration patterns have also been reported. Both northern Aboriginal peoples and scientists have reported significant changes in the hunting patterns of predators such as the polar bear. For example, Ian Sterling, one of the world's leading experts on the North American polar bear has noted that the polar bear population inhabiting the Hudson Bay region has become smaller. He attributes this to the earlier melting of the ice cover on Hudson Bay, which has made it more difficult for the bears to hunt seal. The Canadian Ice Services of Environment Canada has noted that the ice cover has decreased since the mid-1970s. Satellite data show that the ice cover has steadily been decreasing. Huebert, 2001: 87.
- ¹⁶⁷ The evidence indicates that only 30 years of warmer temperatures at the end of the twentieth century have affected the phenology of organisms, the range and distribution of species, and the composition and dynamics of communities. These examples, spanning the previous century and encompassing most major taxa and ecosystems on Earth, provide linkages between recently observed

changes in natural systems and twentieth century climate change. Walther et al, 2002: 394. A climate “fingerprint” is discernible in natural systems. The most rigorous studies within the United States provide strong evidence that climate change has affected the timing of biological events in at least three taxa (i.e., groups of related species). They also provide strong evidence that at least three taxa have shifted their ranges in response to climate change and that climate change has altered ecological communities and processes. Further, very few instances of biotic change run completely counter to climate-change predictions, and the findings of many of the U.S. studies are mirrored by studies elsewhere around the world. Galbraith and Parmesan, 2004. Common changes in the timing of spring activities include earlier breeding or first singing of birds, earlier arrival of migrant birds, earlier appearance of butterflies, earlier choruses and spawning in amphibians and earlier shooting and flowering of plants. In general, spring activities have occurred progressively earlier since the 1960s. Walther et al, 2002.

- ¹⁶⁸ The Alaskan tundra has switched from being a net sink of CO₂ (absorbing and storing more carbon from the atmosphere than is released) to being a net source of CO₂ (releasing more carbon than is stored), because warmer winters have allowed dead plant matter previously stored in the soil to decompose and release CO₂. Like the tundra, boreal forests have become carbon sources because of reduced growth due to climate-mediated increases in water stress, pest outbreaks, and wildfires. Conversely, many of the forests of the lower 48 states have switched in the opposite direction—becoming carbon sinks in recent decades. This transition is attributed to regrowth of forests following logging and abandonment of agricultural fields. However, it is expected to stop as soon as the forests mature. Galbraith and Parmesan, 2004: iv. In Antarctic terrestrial ecosystems, visually dramatic examples of biological changes in response to climatic warming include the colonization by macroscopic plants (largely mosses) of previously bare or newly exposed ground and the rapid expansion in extent and numbers of the only two higher plants present on the continent. Walther et al, 2002: 392.
- ¹⁶⁹ With general warming trends, these ‘climate envelopes’ become shifted towards the poles or higher altitudes. To the extent that dispersal and resource availability allow, species are expected to track the shifting climate and likewise shift their distributions poleward in latitude and upward in elevation. Walther et al, 2002: 392.
- ¹⁷⁰ Poised near their upper thermal limits, coral reefs have undergone global mass bleaching events whenever sea temperatures have exceeded long-term summer averages by more than 1.0 8C for several weeks. Reef-building corals, which are central to healthy coral reefs, are currently living close to their thermal maxima. They become stressed if exposed to small slight increases (1-2oC) in water temperature and experience coral bleaching. Coral bleaching occurs when the photosynthetic symbionts of corals (zooxanthellae) become increasingly vulnerable to damage by light. Six periods of mass coral bleaching have occurred since 1979 and the incidence of mass coral bleaching is increasing in both frequency and intensity. The most severe period occurred in 1998, in which an estimated 16% of the world’s reef-building corals died. See Walther et al, 2002: 392 and Hoegh-Guldberg, 1999 for more detailed descriptions.
- ¹⁷¹ Food security presents a particularly worrisome problem, given the continuing growth of the world’s population and the leveling off in production of key foodstuffs such as wheat and rice. Increased crop damage from droughts, floods, and storms could make famines not only more frequent but far more difficult to deal with. See Francis and Hengeveld, 1998: 26.
- ¹⁷² The Inuvialuit Community in Sachs Harbour, reported commonplace and cumulative changes that threaten their cultural future: melting permafrost resulting in beach slumping; increased snowfalls; longer sea ice-free seasons; new species of birds and fish (barn owls, mallard and pin-tailed ducks and salmon) near the community; a decline in the lemming population, the basic food for Arctic fox, a valuable harvested species; and generally a warming trend. See Fenge, 2001: 82.
- ¹⁷³ Climate-linked invasions might also involve the immigration of unwanted neighbours such as epidemic diseases. There is much evidence that a steady rise in annual temperatures has been associated with expanding mosquito-borne diseases in the highlands of Asia, East Africa and Latin America. Overall, trends of range changes show remarkable internal consistency between studies relating to glaciers, plant and insect ranges and shifting isotherms. See Walther et al, 2002 and Pollution Probe, 2004.
- ¹⁷⁴ See Harrison and Whittington, 1998.
- ¹⁷⁵ Each model must use estimates of the amount of CO₂ emissions from humans. Policies and agreements, such as the Kyoto Agreement, are established so humans will reach the lower estimates of CO₂ emissions and therefore experience less Climate Change. The models being used to predict future warming still contain too much uncertainty. Although they have improved and continue to evolve, the global climate system is very complex, making it difficult to accurately account for every factor. Greenlearning.ca, 2006.

- ¹⁷⁶ Changes that are already being observed are to the rising sea levels, changes in the water cycle (precipitation increasing or decreasing in areas, ocean temperatures etc) and air temperatures (increasing and decreasing in certain areas effecting other systems such as the water cycle and oceans). Vulnerable areas to water level changes are low-lying nations and islands states, coastlines and deltas, regions already vulnerable to drought and desertification, fragile mountain ecosystems. Greenlearning.ca, 2006. Presently, the human species have major impacts on other species such as: reducing the amount of the Earth's surface available to those other species, interfering with their food sources, changing the temperature and chemical composition of their habitats. These impacts are and will be increased due to human induced climate changes, AAAS, 1993: 57. Based on our current understanding of climate change science, future climate change impacts will result in: ice cap and glacier reduction, species movements and desertification. Examples of changes occurring in socio-economic systems will include: spread of disease, dealing with extreme hot and cold weather conditions, availability and quality of water, Subsistence Hunting, Hydroelectricity, Agriculture, Forestry, Fisheries, human Health, Infrastructure & Tourism and Recreation. Greenlearning.ca, 2006. The indirect effects of climate change will alter the environment and ecosystems in which we live. These indirect effects will occur through insect- and rodent-transmitted diseases (e.g., West Nile virus fever; Lyme disease and Hantavirus Pulmonary Syndrome); increased smog and air pollution; waterborne and food-related illnesses (e.g., giardia, E. coli infection, and shellfish poisoning); and stronger UV radiation, which is a leading cause of skin cancer and. Climate change models that don't take into account any decreases in Greenhouse Gas emissions (the 'business as usual' scenario) estimate 3 billion people will see an increase in 'water stress'. Specifically those in Northern Africa, Middle East and the Indian subcontinent. Godrej, 2001: 57. Pollution Probe, 2004: 14.
- ¹⁷⁷ Canada being in the Northern Latitudes is expected to experience change greater than global averages, the IPCC estimates. Due to the size of Canada and its location on the globe it will experience Climate Change in very specific ways in specific regions and to varying degrees. Arctic and Subarctic Canada will experience the greatest temperature and precipitation changes. Coward and Weaver, 2004: 73-74. Examples of specific changes in specific regions are; In the North the depletion of Sea Ice will affect dependent animals such as Polar Bears and Seals as well as Indigenous hunters who rely heavily on these animals. Also, transportation with regard to ice roads in the winter and shipping in channels will be affected by changing water levels. These activities will affect Canadians economically and socially as well as effecting the environment. The eastern Arctic will experience more severe winter storms and human adaptation must be significant with regards to rapid changes in Northern economies and institutions. The Southern Prairie Provinces will be most affected by water changes due to climate change and therefore agriculture seriously affected. Crops are also affected by higher temperatures, as are pests that are an important factor in farming. Southern Ontario and Southwest Quebec having the Great Lakes and St. Lawrence systems will be affected by changing water levels due to higher evaporation in warmer temperatures. Water management, flash flood potential will also increase in these areas Coward and Weaver, 2004: 75-84.
- ¹⁷⁸ Climate change will impact upon people disproportionately. The actions or inaction of present generations will affect future generations. Many industrialized countries will not suffer the consequences of climate change at the same level as those from less developed nations. People in industrialized countries generate over 62 times more CO₂ pollution per person than in the least industrialized countries. Godrej, 2001: 32. Social tradeoffs are often generational. The cost of benefits received by one generation may fall on subsequent generations. Also, the cost of a social trade-off is sometimes borne by one generation although the benefits are enjoyed by their descendants. AAAS, 1993: 166. Industrialised and developing countries experience the impacts of Climate Change in very disproportionate ways. For example, 96% of all deaths from natural or unnatural disasters happen in the developing world. The spreading of disease is the primary force behind these deaths because of the substantially fewer resources, supports and infrastructure compared to industrialized countries. Godrej, 2001: 48.
- ¹⁷⁹ The Earth's climate system has demonstrably changed on both global and regional scales since the pre-industrial era, with some of these changes attributable to human activities. Human activities have increased the atmospheric concentrations of greenhouse gases and aerosols since the pre-industrial era. The atmospheric concentrations of key anthropogenic greenhouse gases (i.e., carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), and tropospheric ozone (O₃)) reached their highest recorded levels in the 1990s, primarily due to the combustion of fossil fuels, agriculture, and land-use changes. The radiative forcing from anthropogenic greenhouse gases is positive with a small uncertainty range; that from the direct aerosol effects is negative and smaller; whereas the negative forcing from the indirect effects of aerosols on clouds might be large but is not well quantified. See IPCC, 2001.
- ¹⁸⁰ The debate can be seen clearly in Toulain's Article in the National Post titled Canada: Kyoto Possible without hurting economy: CEO's, 2002. Business leaders believe implementing the Kyoto Protocol on climate change can be achieved without causing major economic disruption, says a Financial Post poll. Some 57% of the executives said greenhouse emissions could be cut drastically with little economic impact -- the same position expressed by David Anderson, the Minister of the Environment at this time. Meanwhile, 29% of respondents said they were firmly opposed to the Kyoto Protocol and 13% had no opinion. Steve Kiar, a COMPAS senior partner, said the poll response is surprising because such key business groups as the Canadian Chamber of Commerce, the Canadian Manufacturers and Exporters and the Canadian Association of Petroleum Producers have warned that

implementing the treaty would be devastating for the Canadian economy. In February (2002), the Canadian Manufacturers and Exporters said Kyoto would wipe out 450,000 manufacturing jobs in Canada, and that it would cost the economy up to \$40-billion and force a radical lifestyle change on people. Toulin, 2002.

For a skeptics article see also Moore, 1998, Warmer Earth Might be a Welcome Trend. An excerpt supposedly from a Wall Street Journal Article written by Pete Du Pont, the former governor of Delaware stated, "So what is the reality about global warming and its impact on the world? A new study released this week by the National Center for Policy Analysis, "Climate Science: Climate Change and Its Impacts"" looks at a wide variety of climate matters, from global warming and hurricanes to rain and drought, sea levels, arctic temperatures and solar radiation. It concludes that "the science does not support claims of drastic increases in global temperatures over the 21st century, nor does it support claims of human influence on weather events and other secondary effects of climate change." "The environmental pessimists tell us, as in Time magazine's recent global warming issue, to "Be Worried. Be Very Worried," but the truth is that our environmental progress has been substantially improving, and we should be very pleased." Du Pont, 2006.

¹⁸¹ Scientists are linked to other scientists worldwide both personally and through international scientific organizations. AAAS, 1993: 177.

¹⁸² See Pollution Probe, 2004.

¹⁸³ The increase of CO₂ in the atmosphere was first recognized in the late 1800's. Scientists, Politicians and Industries have debated and met about climate change in many historically significant speeches and conferences. Some have had a significant impact on making Climate Change an important social problem and some have created conflict and debate, many issues are still very unresolved. The following is a timeline including significant events in Climate Change history.

1827: French polymath Jean-Baptiste Fourier predicts an atmospheric effect keeping the Earth warmer than it would otherwise be. He is the first to use a greenhouse analogy.

1863: Irish scientist John Tyndall publishes a paper describing how water vapour can be a greenhouse gas.

1890s: Swedish scientist Svante Arrhenius and an American, P C Chamberlain, independently consider the problems that might be caused by CO₂ building up in the atmosphere. Both scientists realise that the burning of fossil fuels could lead to global warming, but neither suspects the process might already have begun.

1890s to 1940: Average surface air temperatures increase by about 0.25 °C. Some scientists see the American Dust Bowl as a sign of the greenhouse effect at work.

1940 to 1970: Worldwide cooling of 0.2°C. Scientific interest in greenhouse effect wanes. Some climatologists predict a new ice age.

1957: US oceanographer Roger Revelle warns that humanity is conducting a "large-scale geophysical experiment" on the planet by releasing greenhouse gases. Colleague David Keeling sets up first continuous monitoring of CO₂ levels in the atmosphere. Keeling soon finds a regular year-on-year rise.

1979: First World Climate Conference adopts climate change as major issue and calls on governments "to foresee and prevent potential man-made changes in climate."

1985: First major international conference on the greenhouse effect at Villach, Austria, warns that greenhouse gases will "in the first half of the next century, cause a rise of global mean temperature which is greater than any in man's history." This could cause sea levels to rise by up to one metre, researchers say. The conference also reports that gases other than CO₂, such as methane, ozone, CFCs and nitrous oxide, also contribute to warming.

1987: Warmest year since records began. The 1980s turn out to be the hottest decade on record, with seven of the eight warmest years recorded up to 1990. Even the coldest years in the 1980s were warmer than the warmest years of the 1880s.

1988: Global warming attracts worldwide headlines after scientists at Congressional hearings in Washington DC blame major US drought on its influence. Meeting of climate scientists in Toronto subsequently calls for 20% cuts in global CO₂ emissions by the year 2005. UN sets up the Intergovernmental Panel on Climate Change (IPCC) to analyse and report on scientific findings.

1990: The first report of the IPCC finds that the planet has warmed by 0.5°C in the past century. IPCC warns that only strong measures to halt rising greenhouse gas emissions will prevent serious global warming. This provides scientific clout for UN negotiations for a climate convention. Negotiations begin after the UN General Assembly in December.

1991: Mount Pinatubo erupts in the Philippines, throwing debris into the stratosphere that shields the Earth from solar energy, which helps interrupt the warming trend. Average temperatures drop for two years before rising again. Scientists point out that this event shows how sensitive global temperatures are to disruption.

1992: Climate Change Convention, signed by 154 nations in Rio, agrees to prevent "dangerous" warming from greenhouse gases and sets initial target of reducing emissions from industrialised countries to 1990 levels by the year 2000.

1994: The Alliance of Small Island States - many of whom fear they will disappear beneath the waves as sea levels rise - adopt a demand for 20% cuts in emissions by the year 2005. This, they say, will cap sea-level rise at 20 centimetres.

1995: The hottest year recorded to date. In March, the Berlin Mandate is agreed by signatories at the first full meeting of the Climate Change Convention in Berlin. Industrialised nations agree on the need to negotiate real cuts in their emissions, to be concluded by the end of 1997.

In November, the IPCC states that current warming "is unlikely to be entirely natural in origin" and that "the balance of evidence suggests a discernible human influence on global climate". Its report predicts that, under a "business as usual" scenario, global temperatures by the year 2100 will have risen by between 1°C and 3.5°C.

1996: At the second meeting of the Climate Change Convention, the US agrees for the first time to legally binding emissions targets and sides with the IPCC against influential sceptical scientists. After a four-year pause, global emissions of CO₂ resume their steep climb, and scientists warn that most industrialised countries will not meet Rio agreement to stabilise emissions at 1990 levels by the year 2000.

1997: Kyoto Protocol agrees legally binding emissions cuts for industrialised nations, averaging 5.4%, to be met by 2010. The meeting also adopts a series of flexibility measures, allowing countries to meet their targets partly by trading emissions permits, establishing carbon sinks such as forests to soak up emissions, and by investing in other countries. The precise rules are left for further negotiations. Meanwhile, the US government says it will not ratify the agreement unless it sees evidence of "meaningful participation" in reducing emissions from developing countries.

1998: Follow-up negotiations in Buenos Aires fail to resolve disputes over the Kyoto "rule book", but agree on a deadline for resolution by the end of 2000. 1998 is the hottest year in the hottest decade of the hottest century of the millennium.

2000: IPCC scientists re-assess likely future emissions and warn that, if things go badly, the world could warm by 6°C within a century. A series of major floods around the world reinforce public concerns that global warming is raising the risk of extreme weather events. But in November, crunch talks held in The Hague to finalise the "Kyoto rule book" fail to reach agreement after EU and US fall out. Decisions postponed until at least May 2001.

2001: The new US president, George W Bush, renounces the Kyoto Protocol because he believes it will damage the US economy. After some hesitation, other nations agree to go ahead without him. Talks in Bonn in July and Marrakech in November finally conclude the fine print of the protocol. Analysts say that loopholes have pegged agreed cuts in emissions from rich-nation signatories to less than a third of the original Kyoto promise. Signatory nations urged to ratify the protocol in their national legislatures in time for it to come into force before the end of 2002.

2002: Parliaments in the European Union, Japan and others ratify Kyoto. But the protocol's complicated rules require ratification by nations responsible for 55% of industrialised country emissions, before it can come into force. After Australia joins the US in renegeing on the deal, Russia is left to make or break the treaty, but hesitates. Meanwhile, the world experiences the second hottest year on record.

2003: Globally it is the third hottest year on record, but Europe experiences the hottest summer for at least 500 years, with an estimated 30,000 fatalities as a result. Researchers later conclude the heat wave is the first extreme weather event almost certainly attributable to man-made climate change. Extreme weather costs an estimated record of \$60 billion this year. 2003 also sees a marked acceleration in the rate of accumulation of greenhouse gases. Scientists are uncertain if it is a blip or a new, more ominous trend. Meanwhile Russia blows hot and cold over Kyoto.

2004: A deal is struck on Kyoto. President Putin announces in May that Russia will back the Protocol - and the EU announces it will support Russia's membership of the World Trade Organization. On 18 November, the Russian parliament ratifies the protocol, paving the way for it to come into force in 2005.

2005: Second warmest year on record. Researchers link warming to a record US hurricane season accelerated melting of Arctic sea ice and Siberian permafrost, and apparent disruption of the global ocean current that warms Europe. The Kyoto Protocol comes into force. In December, Kyoto signatories agree to discuss emissions targets for the second compliance period beyond 2012, while countries without targets, including the US and China, agree to a "non-binding dialogue" on their future roles in curbing emissions.

New Scientist, 2006.

¹⁸⁴ The original article written by Garret Hardin in 1968 addresses the tragedy of the commons concerning not climate change, but population growth. Hardin describes a situation where a pasture is open to all where each herdsman can keep as many cattle as possible on the commons. Each herdsman tries to rationalize his gain thinking, "What is the utility to me of adding one more animal to my herd?". The answer includes one negative and one positive utility. Firstly, the herdsman benefits from one additional animal and later the sale of that animal. The negative utility concerns the overgrazing of the commons created by that one animal. This does not have an equal negative impact to the herdsman compared to the positives. The herdsman share this with others. Hardin concludes, "...Each man is locked into a system that compels him to increase his herd without limit - in a world that is limited. Ruin is the destination toward which all men rush, each pursuing his own best interests in a society that believes in the freedom of the commons. Freedom in a commons brings ruin to all." Pojman (ed.) 1997: 306. More information on the Tragedy of the Commons can be found at, en.wikipedia.org/wiki/Tragedy_of_the_commons - viewed June 27 2006. The original essay can be found on the Internet here, <http://dieoff.org/page95.htm> - viewed June 27 2006.

- ¹⁸⁵ The majority of the world's scientists acknowledge climate change as a phenomenon that is occurring and one that will have serious repercussions. These include the International Council of Science found at www.icsu.org, National Academies of Science for Canada, United States, Britain, Germany, Italy, France, Japan, Russia, Brazil, China, India and others, the American Geophysical Union, American Meteorological Society, NASA's Goddard Institute for Space Studies, the National Oceanic and Atmospheric Administration, the Environmental Protection Agency, the US National Centre for Atmospheric Research, and the Canadian Meteorological and Oceanographic Society.
- ¹⁸⁶ The media constructs what many citizens scientifically and politically know about Climate Change. "Our research suggests that the US, with differing industries, predominantly dominated by the fossil fuel industry, in comparison to New Zealand and Finland, has a significant impact on the media coverage of global warming. The U.S.'s media states that global warming is controversial and theoretical, yet the other two countries portray the story that is commonly found in the international scientific journals. Therefore, media acting as one driving force is providing citizens with piecemeal information that is necessary to assess the social, environmental and political conditions of the country and world." Dispensa and Brulle, 2003: 74. The dominant model of the public media is one that is characterized by "the manipulative deployment of media power to procure mass loyalty, consumer demand, and compliance with systemic imperatives." Habermas 1992:453. Dispensa and Brulle, 2003: 78. Research suggests a typical paper will reject over 75% of the daily news. This illustrates the impact they can have on what news stories get printed and what messages are sent to the viewer. Dispensa and Brulle, 2003: 80. It has also been concluded that while scientific and political forces are both important to the debate, scientists become less dominant sources as the issue matures. As this occurs, the emphasis of the news coverage concurrently shifts away from a presentation of the issue in terms of its causes and problematic nature and toward a presentation more grounded in political debate and the proposal of solutions. Trumbo, 1996: 281.
- ¹⁸⁷ A number of industry groups and others who believe that action on climate change is not in their self interest use various means to prevent change. Methods include media and political process manipulation, attempts to discredit the science, and instilling confusion by promoting obscure scientific representatives who disagree with the majority held view in the scientific community. These actions have occurred with other issues where science has identified problems that require changes for the good of society but that are contrary to the economic interests of a sector. The dairy industry initially opposed pasteurization early in the 20th century by trying to discredit the science that demonstrated that pasteurization reduced disease. Similarly the pesticide industry worked to discredit scientific findings that pesticide use caused severe problems in ecosystems. This approach to scientific findings for economic reasons differs from that which occurs in the scientific community. Here new ideas that do not mesh well with mainstream ideas in science often encounter vigorous criticism because of established knowledge patterns in a discipline. AAAS, 1993: 13.

Motivation for undermining of climate change science most often relates to economic self interest. Changes to reduce climate change may require a reduction of the value of current infrastructure and manufacturing investments, reduction in use of particular resources and other economic challenges.

For example various organizations have developed significant campaigns against climate change including the Global Climate Coalition founded in 1989 by 46 corporations and trade associations representing all major elements of US industry. It funded studies on the economics of the cost of mitigating climate change, which formed the basis of their 1997/1998 multi-million dollar advertising campaign against the Kyoto Protocol. Similarly the Greening Earth Society founded on Earth Day 1998 by the Western Fuels Association promoted the view that increasing levels of atmospheric CO₂ are good for humanity. For further discussion on global warming skeptics see the Union for Concerned Scientists' website http://www.ucsusa.org/global_warming/science/skeptic-organizations.html. - Viewed September 3 2006.

- ¹⁸⁸ The response to climate change is gathering strength despite continued resistance to climate change from various sectors of the economy. Manitoba announced in June 2002 that the provincial government intends to meet and even exceed its targets for reducing greenhouse gas emissions under the international Kyoto Protocol. <http://www.gov.mb.ca/est/climatechange/takeaction/>. Cities such as Regina have initiated actions to inform citizens

about the challenge http://www.regina.ca/content/info_services/climate/greenribbon/committee.shtml

Many non-governmental organizations focus on the climate change issue. An example is the David Suzuki foundation - http://www.davidsuzuki.org/Publications/Climate_Change_Reports/ Specific actions are promoted through the Clean Air Pass - <http://www.cleanairpass.com/> - Viewed September 3 2006.

Some members of the corporate community are developing responses to climate change in advance of government policy in the area.

- ¹⁸⁹ There are some methods to deal with the problem involve maximizing carbon uptake and offsetting humans excess greenhouse gas emissions. This can be done by creating Carbon stocks and sinks with forests and agriculture. Agriculture can also be used as a biofuel instead of fossil fuels. Coward and Weaver, 2004: 239. Individual actions include installing energy efficient light bulbs, replacing appliances with highest efficiency models, wash clothes in cold water, turn down your thermostat 1C, Reduce air travel, reduce consumption, become a vegetarian and buy locally produced seasonal produce. Godrej, 2001: 135. Some governments are undertaking efforts at the provincial, national and international levels to response to climate change. To various degrees, governments try to bring about social change or to impede it through policies, laws, incentives, or direct coercion. Sometimes such efforts achieve their intended results and sometimes they do not AAAS, 1993: 163. The United Nations Intergovernmental panel on Climate Change (IPCC) conducts research on Climate Change and hold conferences to bring together scientists, economists and politicians to spread knowledge and make change. Godrej, 2001: 19. International agreements such as the Kyoto accord have attempted to control the greenhouse gas emissions and bring them down to previous levels.
- ¹⁸⁹ For example, Insurance companies in industrialized countries fear that extreme weather events could bankrupt the industry and destabilize world markets. Godrej, 2001: 35. Andersson and Wallin, 2000. The growing interdependence of world social, economic, and ecological systems does not always bring greater worldwide stability and often increases the costs of conflict AAAS, 1993: 174.
- ¹⁹⁰ A drastic reduction in CO2 emission would have repercussions throughout the web of dependence through its impact on the economy, business activities, infrastructure, social institutions, and the environment. The prices of implementing a carbon tax are less than formerly imagined. See Jeffery Sachs article, Pay for it now, or Pay for it later. Globe and Mail. June 19, 2006. A13.
- ¹⁹¹ At present there is no economic disincentive for the user applied when carbon based fossil fuels are used. These costs (climate change, smog, resource depletion etc) are born by all people of the world, though unevenly, even though some of these people may not have enjoyed the benefits. Until the cost of using fossil fuels is borne by the users, it is unlikely that alternative energy sources will be used to the degree necessary.
- ¹⁹² Moreover, there are two very sound reasons why we should seek global agreement on adaptation. First, our current vulnerability to existing climatic variability is very costly. For instance, about 640 million people are at risk of hunger now. Poverty is the root cause, but much of the year-to-year variability in hunger is due to drought. By drought proofing those at risk now we could secure their present livelihood and reduce the impact of future climate change. There are many kinds of such 'win-win' solutions that serve both our present and future needs, such as increasing irrigation efficiency, breeding more drought-resistant crops and developing buffer stocks of food. Second, adapting to climatic variability has a substantially greater effect of reducing impact than does mitigation. Consider, for example, the effect of reducing water demand by 5 and 10 per cent below current projections for 2050. Reducing water demand by just 5 per cent has four times as great an effect as reducing emissions by 30 per cent. Broadly, the same stress-reducing outcomes would stem from similar demand reductions in other impact sectors (such as reducing soil erosion, or reducing crop yield losses to pests and diseases). Parry et al 1998.