Current Climate Studies
3:

WHAT DO WE KNOW? HIGHLIGHTS AND KEY FINDINGS ABOUT CLIMATE AND CLIMATE CHANGE

1. Print this file. Also answer the "Concept of the Week" questions in the *Weekly Climate News* File. (Check for additional *News* updates during the week.)

2. Complete the Investigation by responding to the *Chapter Progress Questions* (*Study Guide* binder) and the Investigations 3A and 3B from the *Climate Studies Investigations Manual*, and this *Current Climate Study*.

What Do We Know From the Observational Record?

Change in the state of Earth's climate system is evidenced by changes in its mean surface air temperature. The global temperature record from 1880 to 2011 based on NASA's Goddard Institute for Space Studies (NASA GISS) analyses is displayed in **Figure 1** in terms of temperature anomalies (deviations) in Celsius degrees relative to the 1951-1980 mean temperature. Draw a solid horizontal line on the graph at the .0 Celsius degree temperature anomaly value representing the 1951-1980 the long-term mean for reference.

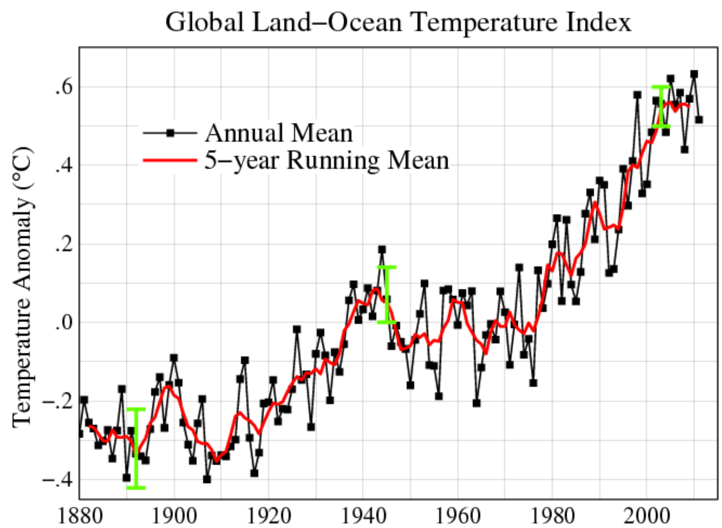

Figure 1. Global temperature anomalies from 1880 to 2011 based on the 1951-1980 average. Black line connects annual mean values. Red line denotes 5-year mean or moving average. [NASA GISS]

1. Figure 1 shows that over the entire period of record the trend of Earth's mean surface air temperature was generally, but not consistently, upward. Compared to the entire period of record, Earth's mean annual surface air temperatures from the mid-1970s through 2011 exhibited a more steady **[(*increase*)(*decrease*)]**.

NOAA's National Climatic Data Center (NCDC) reported that the 2011 combined global land and ocean surface temperature tied with 1997 as the 11th warmest year on record, at 0.51 C degrees (0.92 F degrees) above the 20th century average of 13.9°C (57.0°F). This marks the 35th straight year that the yearly global temperature was above average. The warmest years of record were 2005 and 2010, having temperatures that were 0.64 C degrees (1.15 F degrees) above average.

In **Figure 2**, global surface temperatures during 2011 are compared to the average of the 1975-2011 time period. Warm colors (e.g., yellows) denote positive anomalies, or higher than average temperatures, and cool colors (e.g., blues) identify negative anomalies, or lower than average temperatures. White denotes no departure from the 1975-2011 average.

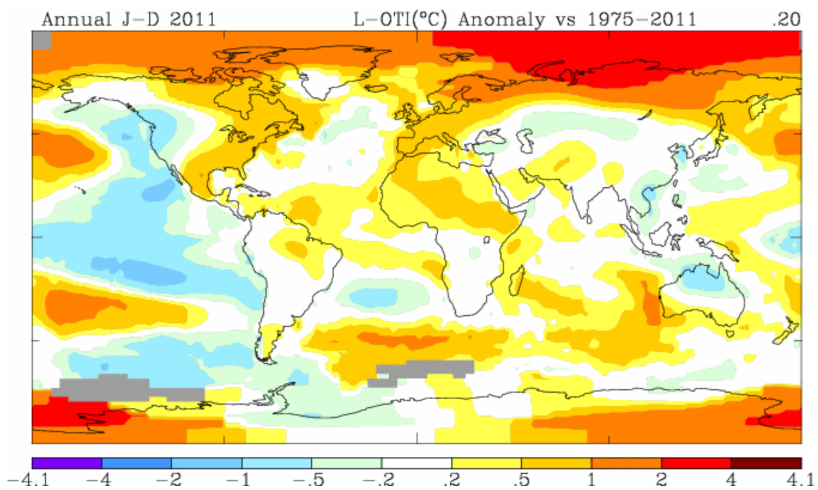

Figure 2. Surface temperature anomalies of annual 2011 data compared with 1975-2011 data. Gray areas signify missing data. [NASA GISS]

2. Figure 2 shows that temperature change is not uniform across the globe. It shows that in 2011 the **[(*__Southern Hemisphere higher latitudes__*)(*__equatorial region__*)(*__Northern Hemisphere higher latitudes__*)]** experienced the greatest warming compared to the averages of the 1975-2011 time period.

3. Figure 2 shows that **[(*__only warming__*)(*__only warming or no temperature change__*)(*__warming, no temperature change, or cooling__*)]** occurred in 2011 in various locations worldwide relative to the 1975-2011 time period. This variability is called ***geographical non-uniformity***. Compare temperature anomalies across the U.S.

[Optional: To explore global temperature change based on Global Historical Climatology Network data, go to http://data.giss.nasa.gov/gistemp/maps/. There, you can interactively produce graphics. To start, select "Anomalies" for Map Type, "Annual (Jan-Dec)" as Mean Period, key in 2011 and 2011 as Time Interval and 1975 and 2011 as Base Period, select "1200 km" for Smoothing Radius, select "regular" for Projection type, and click on "Make Map" button. Compare with Figure 2.]

Figure 3 displays the annual and 5-year running mean surface air temperatures in the contiguous United States (1.6% of Earth's surface) relative to the 1951-1980 mean. Draw a solid horizontal line on the graph at the 0 value representing the 1951-1980 mean.

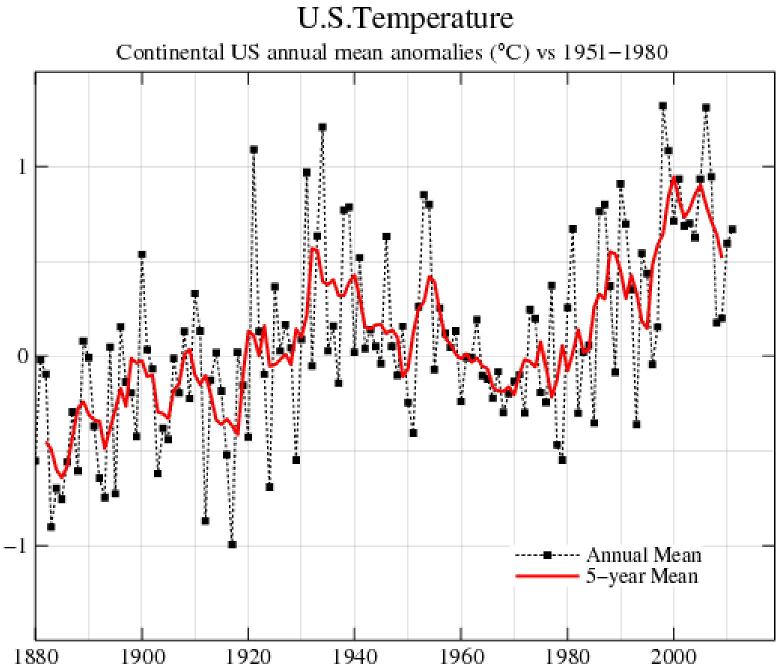

Figure 3. U.S. annual mean temperature departures (anomalies) from the 1951-1980 mean. Anomaly values in Celsius degrees. [NASA GISS]

4. By 2011, the last year reported in Figure 3, the contiguous U.S. had experienced 15 years in a row with annual temperatures above the 1951-1980 mean. Comparison of Figure 3 with Figure 1 shows that from 2010 to 2011, continental U.S. temperatures trended in the**[(*same*)(*opposite*)]** direction compared to the global land-ocean temperature index. Note from the comparison of the two graphs that the variability of temperature from year to year is greater for the smaller geographical area.

Among other measures employed as climate indicators is the global mean sea level. **Figure 4** presents sea level changes derived from measurements acquired with the TOPEX and Jason series of satellite radar altimeters. Calibrated against a network of tide gauges to subtract seasonal and other variations, these determinations allow for an estimate of the global mean sea level change rate. Figure 4 covers the period from 1993 to late 2011.

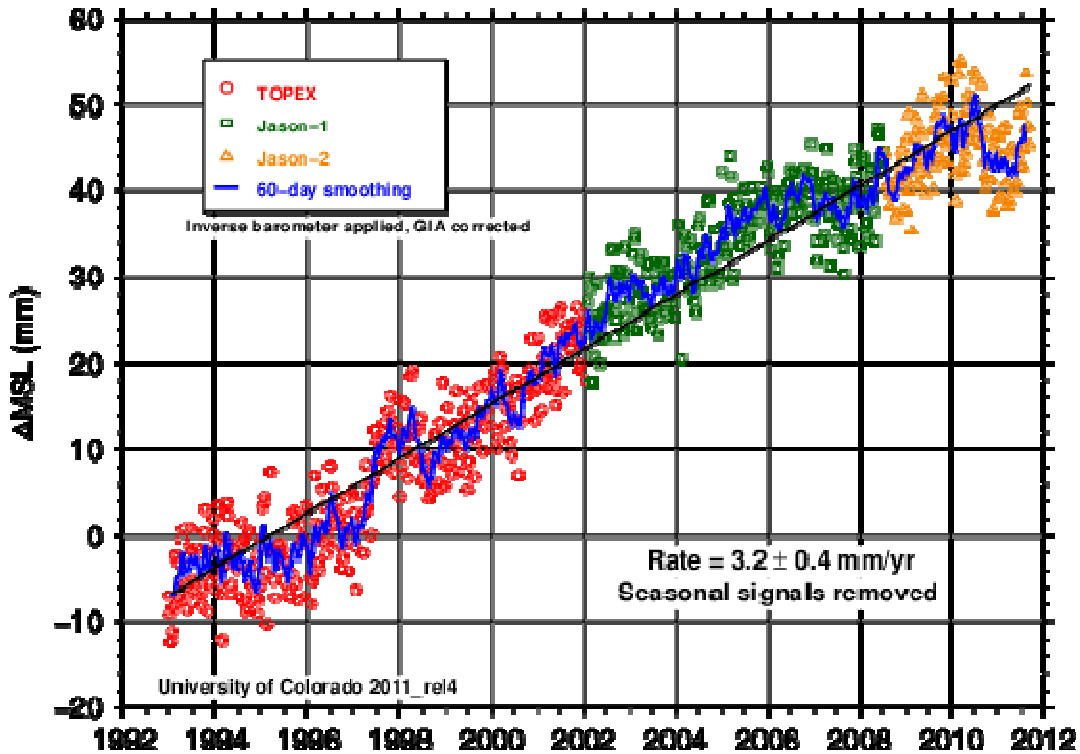

Figure 4. Global Mean Sea Level with seasonal signals removed. [University of Colorado Sea Level Research Group]

5. According to Figure 4, the straight black trend line ("line of best fit") shows that in the 18 years of satellite data from 1993 through much of 2011, the rate of change in mean sea level (MSL) averaged approximately **[(*–3.2*)(*0*)(*+3.2*)]** mm/yr.

6. The data plots and the blue 60-day smoothing (running average) curve in Figure 4 show that beginning in 2010 until mid-2011 the global mean sea level **[(*dropped*)(*remained steady*)(*rose*)]**.

This short-term change in global mean sea level from 2010 until mid-2011, shown best by the blue 60-day smoothing curve is contrary to the long-term trend. Is this an indication of the beginning of a permanent return to earlier and lower mean sea levels? NASA scientists are confident that this is a temporary drop due to strong La Niña conditions that occurred in the Tropical Pacific Ocean in much of 2010 and into 2011. La Niña produces abnormally high rainfall over land, which temporarily transfers large volumes of water from the ocean to land surfaces and results in a measureable change in sea level. With the drainage of the water back to the ocean, the mean sea level should return to its long-term trend. In fact, in late 2011 sea level began rising again. A lesson to be learned is that marked changes in climate indicators might simply be part of natural climate variability. The lowering of the global average temperature by volcanic eruptions is another example of natural climate variability lasting only a year or two.

The Implications of Climate Change and Urgency for Action:

The ***AMS Climate Paradigm***, stated on page 21 of the course textbook, includes a description of why there is growing concern about the observed and anticipated climate change:

Climate is inherently variable and now appears to be changing at rates unprecedented in recent Earth history. Human activities, especially those that alter the composition of the atmosphere or characteristics of Earth's surface, play an increasingly important role in the climate system. Rapid climate changes, natural or human-caused, heighten the vulnerabilities of societies and ecosystems through impacts such as those on water resources, food supply, energy demand, human health, biological systems on which we depend, and national security. These vulnerabilities are global to local in scale and call for increased understanding and surveillance of the climate system and its sensitivity to imposed changes. Scientific research focusing on key climate processes, expanded monitoring, and improved modeling capabilities are already increasing our ability to predict the future climate. Although incomplete, our current understanding of the climate system and the far-reaching risks associated with climate change call for the immediate preparation and implementation of strategies for sustainable development and long-term stewardship of Earth.

7. The *Paradigm* points out that rapid climate change, whether natural or human-caused, places stress on **[(*societies*)(*ecosystems*)(*both of these*)]**.

8. The *Paradigm* implies that the current knowledge about the workings of Earth's climate system and the far-reaching risks associated with climate change is substantial, although not complete. At the same time, it calls for **[(*immediate initiation of*)(*prudent delay in*)]** the preparation and implementation of strategies for sustainable development (meeting the needs of the present without compromising the ability of future generations to meet their own needs) and long-term stewardship of Earth.

The **U.S. Global Change Research Program (USGCRP)** provides a comprehensive state of knowledge report as part of the nation's effort to provide sound and thorough science-based information for policy formulation and the setting of climate change research priorities. On the course website, go to the Societal Interactions and Climate Policy section and click on "US Global Change Impacts Report". Under the U.S. Climate Impacts Report - Full Report heading, click on "Executive Summary".

9. The Executive Summary begins by stating that "warming of the climate is unequivocal" and that the global warming observed in the past five decades is due primarily to **[(*natural*)(*human-induced*)]** emissions of heat-trapping gases. [Note: The USGCRP uses the term *heat-trapping gases* to describe atmospheric gases that absorb and emit infrared radiation (e.g., water vapor, carbon dioxide, methane).]

10. After presenting projections of warming over this century, the Executive Summary states that future temperature increases are likely to be less severe if emissions of global heat-trapping gases are cut substantially. It further states that the **[(*earlier*)(*later*)]** the cuts in

emission, the greater their effect in reducing climate change than comparable reductions made later.

11. The Executive Summary mentions two major categories of actions society can take to respond to the climate challenge. **[(*Mitigation*)(*Adaptation*)]** refers to options for limiting climate change (e.g., reducing emissions of heat-trapping gases or enhancing their removal from the atmosphere) and the other term refers to adjustments in response to actual or expected climate change to reduce harm or exploit beneficial opportunities.

12. The Executive Summary ends with a listing of ten Key Findings, each of which is treated in detail later in the Report. One example of a key finding is that climate change will interact with many social and environmental stresses (e.g., pollution, population growth) causing larger impacts due to their effects being **[(*equal to any single factor*) (*greater than from any of these factors alone*)]**.

The Key Findings that are listed at the end of the Executive Summary of the USGCRP report will be visited in detail as our investigation of global to regional and local climate change challenges are addressed as the course progresses.

Impact of Atmospheric Heat-trapping Gases on Global Temperatures:

The USGCRP Report, along with the AMS/NOAA ***State of the Climate 2010***, the findings of the IPCC, the conclusions of the U.S. National Academies' 2011 ***America's Climate Choices*** reports, and the preponderance of climate change research have identified the increasing concentrations of heat-trapping gases in the atmosphere as the primary forcing agents of global climate change during the past century and into the future. We turn to the ***AMS Conceptual Energy Model*** (**AMS CEM**) to gain insight into how this happens.

Go to the course website and in the Extras section, click on "AMS Conceptual Energy Model", scroll down and click on "Run the AMS CEM". In Investigation 1B you made runs of the AMS CEM when the imaginary planet had one atmosphere and when it had no atmosphere. In the computer simulation of a ***planet with no atmosphere***, you found that with settings of Sun's energy at 100%, 10 cycles of play, and Introductory mode, the number of energy units in the planet's climate system averaged 0.5 energy units per cycle. (Don't trust your memory. Run the AMS CEM with these settings to verify the result.)

You also ran the AMS CEM as a ***planet with one atmosphere*** with settings of Sun's energy at 100% for 10 cycles of play in the Introductory mode. These settings resulted in the number of energy units in the planet's climate system averaging 3.9 energy units per cycle. (Verify this, too, by running the AMS CEM.)

13. The change you observed implies that the addition of an atmosphere changes the amount of energy in the planet's climate system and would result in the temperature of the climate system being **[(*lowered*)(*left unchanged*)(*raised*)]**.

Imaginary Planet with a Double Atmosphere: When set at Two Atmospheres, the AMS CEM graphic depicts two colored (aqua and blue) layers representing a doubling of the atmosphere. The visualization of two atmospheres can be considered analogous to doubling the concentration of heat-trapping carbon dioxide in the atmosphere. In this scenario, an energy unit rising from the planet's surface must make a stop in each atmospheric layer it enters, and any energy unit in an atmospheric layer has equal chances of moving upward or downward in the next cycle of play.

14. Set the AMS CEM to Two Atmospheres, Energy: 100%, 10 cycles, and Introductory mode. Run the model. These settings result in the number of energy units in the planet's climate system averaging **[(*2.9*)(*3.9*)(*4.7*)]** energy units per cycle. Compare this result with those when the AMS CEM ran in no atmosphere and one atmosphere settings as reviewed above.

15. The change you observed implies that a second atmospheric layer changes the amount of energy in the planet's climate system. Assuming that this double-atmosphere scenario is like the doubling of carbon dioxide, it suggests that increasing the concentration of heat-trapping gases in a planet's atmosphere results in **[(*lower*)(*no change in*)(*higher*)]** climate system energy and temperatures. [Note: The earliest climate models, developed in the 1960's at NOAA's Geophysical Fluid Dynamics Laboratory, evaluated the response of a model atmosphere to the doubling of the atmospheric concentration of carbon dioxide.]

Summary:

The observational record definitively shows that global climate change is occurring with trends over the past several decades towards higher temperatures and rising sea level. The AMS CEM provides insight into the impact of heat-trapping gases as the primary forcing agent of climate change evidenced by the rising global mean temperature. The observational record shows that, while trending upward, these changes show considerable variability (ups and downs) and are not uniform around the globe.

The USGCRP ***Global Climate Change Impacts in the United States*** publication provides the most comprehensive report of the climate-related changes have already been observed globally and in the United States. The USGCRP report focuses on observed and projected climate change and its impacts on the United States, particularly in terms of climate change by sector (including water resources, energy supply and use, transportation, agriculture, ecosystems, human health and society) and by regional climate change impacts (e.g., northeast, southwest, coasts).

The USGCRP report will serve as a primary and frequent reference in the weekly installments of DataStreme ECS ***Current Climate Studies***.

Instructions for Communications with Mentor:

Transmit this week's work to your LIT mentor by Monday, 13 February 2012, or as coordinated with your mentor. Include:

- **Chapter Progress Response Form** from the *Study Guide* or the course website.
- **Investigations Answer Form** for 3A and 3B from the *Study Guide* or course website.
- **Current Climate Studies Answer Form** from course website.