Current Climate Studies 3:

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

1. Print this file (and associated linked images if any). 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*) 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?

Mean Surface Air Temperature: Change in the state of Earth's climate system is most commonly evidenced by changes in its mean near-surface air temperature. NASA's Goddard Institute for Space Studies analysis of global annual mean surface temperature change from 1880 to 2015 is presented in **Figure 1**. The temperature anomalies are calculated from the average of annual temperatures during the base period of 1951-1980. The black curve connects annual temperature anomaly values (**▪**). The red curve shows the 5-year running mean.

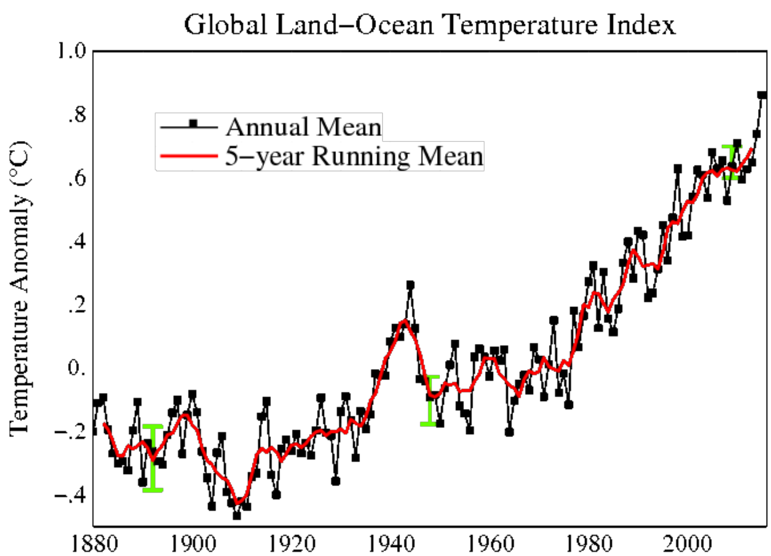

Figure 1. Change in global land-ocean temperatures, 1880-2015.

1. As seen in Figure 1, since about 1910 the trend of Earth's mean near-surface air temperature was generally, although not consistently, upward. According to NASA data plotted in Figure 1, the highest annual mean global land-ocean temperature occurred in ________.

[ ] 1998
[ ] 2005
[ ] 2015

In **Figure 2**, average annual global surface temperatures from 2006 to 2015 are compared to the average of the 1971-2000 base period. Warm colors (e.g., yellows, reds) 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 1971-2000 average. Gray signifies no data. The horizontal line across the figure represents the equator (0º Latitude).

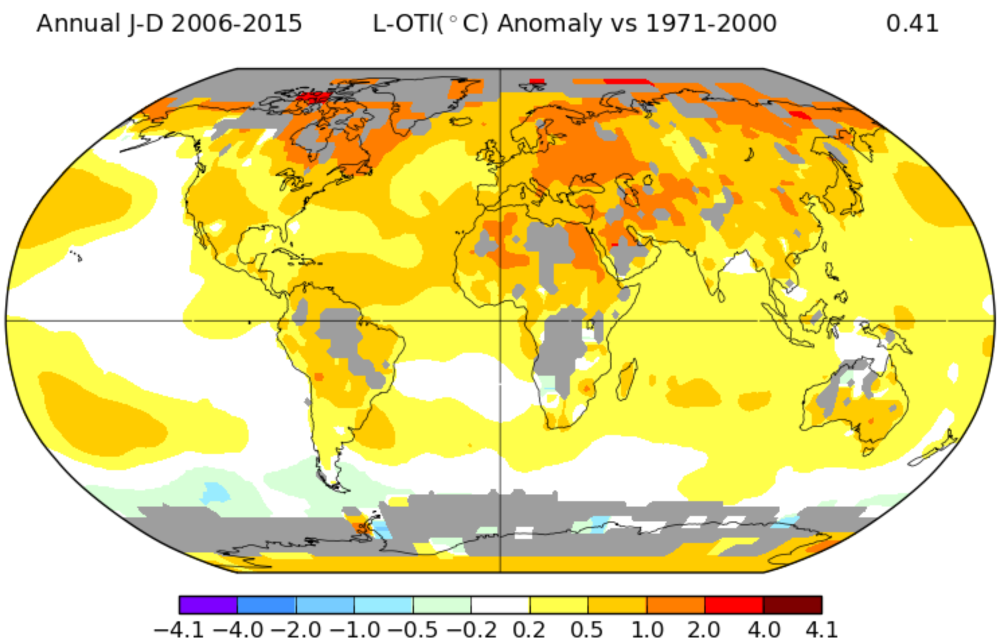

Figure 2. Global surface temperature anomalies averaged from 2006 through 2015 compared to average temperatures from 1971 to 2000. [NASA GISS]

2. Figure 2 shows that ________ occurred in the 2006-2015 time period in various locations worldwide relative to the 1971-2000 time period.

   [ ] only warming
   [ ] only warming and no temperature change
   [ ] warming, no temperature change, and cooling

3. Figure 2 shows the Northern Hemisphere's ________ latitudes experienced the greatest warming when the averages of the 2006-2015 time period are compared to the 1971-2000 average.

[ ] higher
[ ] middle
[ ] tropical

Figure 3 displays the annual and 5-year running mean surface air temperatures in the contiguous United States (1.6% of Earth's surface) from 1880 through 2015 relative to the 1951-1980 mean. The 0 temperature anomaly value position on the vertical scale represents the 1951-1980 mean.

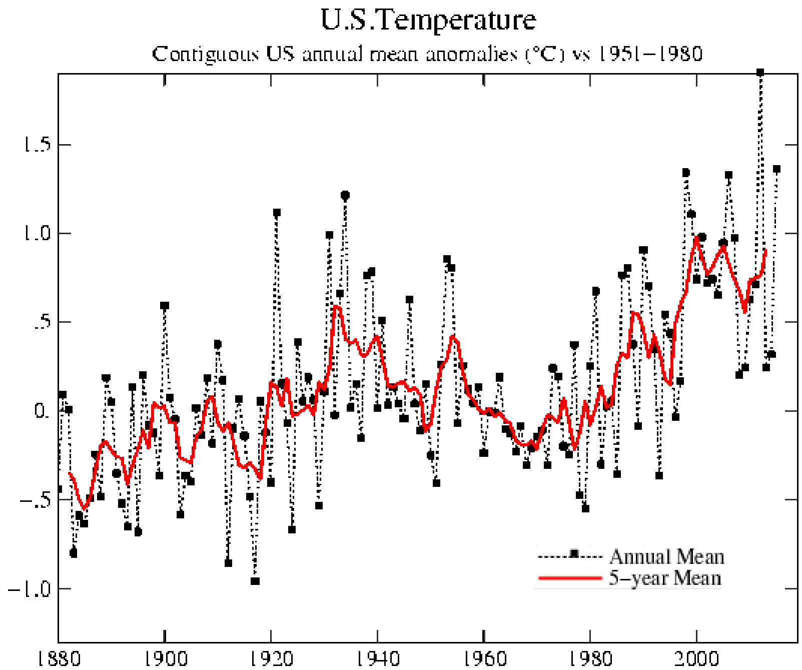

Figure 3. U.S. annual mean temperature anomalies from the 1951-1980 mean through 2015. Anomaly values in C degrees. [NASA GISS]

4. By 2015, the last year reported in Figure 3, the contiguous U.S. had experienced 19 years in a row with annual temperatures above the 1951-1980 mean. Comparison of Figure 3 with Figure 1 shows that the year-to-year variability of the annual mean contiguous U.S. temperature was generally ________ than the variability of the mean annual global land-ocean temperature.

   [ ] greater
   [ ] less

Temperature Variability in the U.S.: To survey variability of surface temperatures throughout the U.S over time, go to: http://ametsoc.org/amsedu/ecs/cag/amscag.html. The *AMS Climate at a Glance Application*, was developed in cooperation with NOAA's National Centers for Environmental Information. Click on "Click to Plot" to view the average annual temperature curve for the contiguous U.S. Note its similarities with Figure 3, including both showing 2012 as the warmest year of record (55.3 °F).

5. Compare annual average surface temperature curves at different U.S. locations by making selections in the *AMS Climate at a Glance Application* State/Region window. Visually compare statewide Connecticut and Missouri graphed temperature data. They demonstrate that temperature trends vary from place to place and from time to time, and that over the period of record indicated ________ more likely experienced climate change.

   [ ] Missouri
   [ ] Connecticut

We will return to the *AMS Climate at a Glance Application* in a later Current Climate Studies segment to determine objectively whether or not a location exhibits evidence consistent with climate change.

Global Mean Sea Level: Among other measures used as climate indicators is the global mean sea level. **Figure 4** presents sea level changes derived from data acquired with the TOPEX and Jason series of satellite radar altimeters as of June 2016. 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, when satellite data became available, to summer 2016.

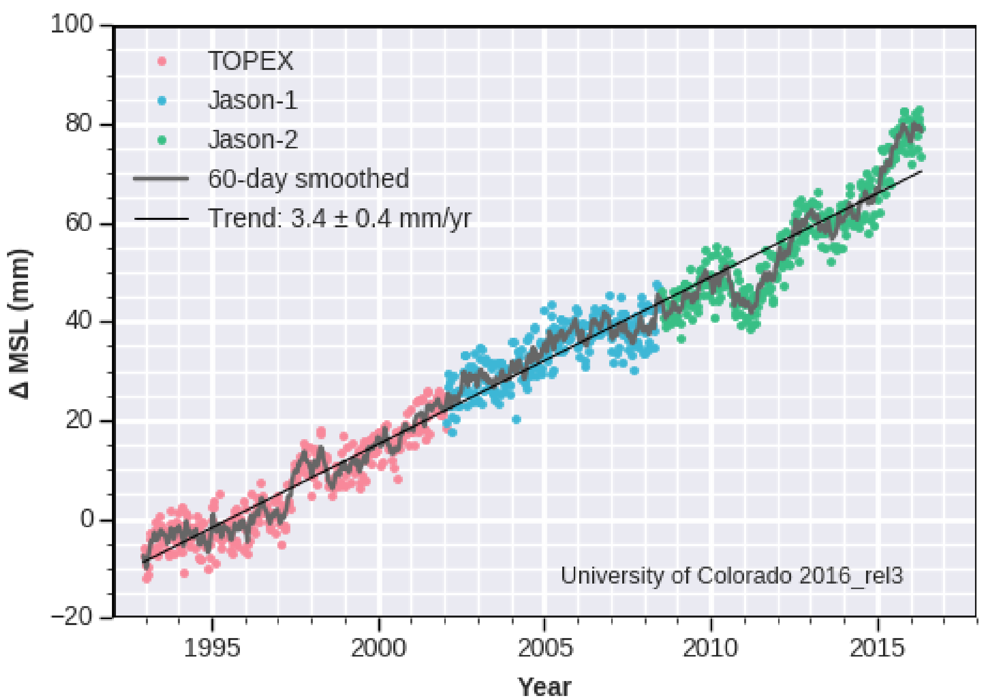

Figure 4. Global Mean Sea Level with seasonal signals removed, released 30 June 2016. [University of Colorado Sea Level Research Group]

6. According to the rate reported in Figure 4, the straight black trend line ("line of best fit") shows that in the years of satellite data from 1993 to June 2016 the rate of change in mean sea level (MSL) averaged approximately ________ mm/yr.

[ ] –3.4
[ ] 0
[ ] +3.4

7. The data plots and the blue 60-day smoothing (running average) curve in Figure 4 show that beginning in mid-2010 until mid-2011 the global mean sea level ________.

[ ] dropped
[ ] remained steady
[ ] rose

This short-term change in global mean sea level from mid-2010 until mid-2011, shown best by the blue 60-day smoothing curve, is contrary to the long-term trend. (Note the subsequent general rise in sea level from mid-2011 to mid-2013.) NASA scientists concluded that the temporary drop in sea level was 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. After the water drained back to the ocean, the mean sea level returned to its long-term trend. A lesson learned from this dip in sea level is that marked changes in climate indicators might simply be part of natural climate variability.

A strong *El Niño* existed in the Tropical Pacific Ocean throughout 2015 into spring 2016. It is characterized by anomalous warming of oceanic surface waters in the eastern tropical Pacific and is accompanied by changes in oceanic and atmospheric circulation plus weather extremes in various parts of the world. Because of the greater expanses of warmer ocean surfaces during a strong *El Niño* episode, it contributes towards the higher global surface temperatures. It also contributes towards higher global mean sea level values, as seen in late 2015 into June 2016 in Figure 4.

The Implications of Climate Change and Urgency for Action:

The ***AMS Climate Paradigm*** includes a description of why there is growing concern about climate change:

Climate is variable and changing, yet is currently shifting at rates unparalleled in recent Earth history. Human activities have become significant drivers of global change, connecting human systems to our planet's biogeophysical processes. This bond positions climate change as part of a complex, coupled human/natural system. Unlike most other life on this planet, our self-awareness informs us, through scientific studies, of our influence on climate. Knowing this allows us to make choices and take actions related to mitigation and adaptation.

Rapid climate change heightens the vulnerabilities of societies and ecosystems, impacting biological systems, water resources, food production, energy demand, human health, and *national security. These vulnerabilities are global to local in scale, calling for increased understanding and surveillance of the climate system and its sensitivity to imposed changes. Scientific research on key climate processes, expanded monitoring, and improved modeling capabilities increase our ability to project the future state of the climate. Climate change is not an isolated problem, but occurs with concurrent environmental change and societal developments that affect our vulnerability and strategies for responding.*

8. The *Paradigm* points out that rapid climate change, whether natural or human-caused, places stress on ________.

   [ ] societies
   [ ] ecosystems
   [ ] both of these

The third *National Climate Assessment* (NCA3) of 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 "National Climate Assessment Highlights", or click on: (http://www.globalchange.gov/sites/globalchange/files/NCA3_Highlights_LowRes-small-FINAL_posting.pdf).

9. The Overview Section, starting on page 4 of the Highlights report, states that "evidence tells an unambiguous story: the planet is warming" and that the global warming observed in the past five decades is due primarily to ________ emissions of heat-trapping gases. [Note: The SGCRP uses the term *heat-trapping gases* to describe atmospheric gases that absorb and emit infrared radiation (e.g., water vapor, carbon dioxide, methane).]

   [ ] natural
   [ ] human-induced

10. The Overview section (p. 10) mentions two categories of actions society can take to respond to the climate challenge. ________ 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 opportunities.

    [ ] Mitigation
    [ ] Adaptation

11. The Overview section ends with a listing of 12 Report Findings, each of which is treated in detail later in the Report. One example of a Report Finding is that climate change threatens human health and well-being in many ways including ________.

[ ] more extreme weather and wild fire
[ ] decreased air quality
[ ] diseases transmitted by insects, food, and water
[ ] all of these

The Report Findings that are listed at the end of the Overview section of the USGCRP NCA 3 report will be visited in detail as our investigation of global to regional and local climate change challenges are addressed.

Impact of Atmospheric Heat-trapping Gases on Global Temperatures:

The USGCRP Report, along with the AMS/NOAA *State of the Climate 2015*, the findings of the IPCC, the conclusions of the U.S. National Academies' 2012 *Climate Change: Evidence, Impacts, and Choices* booklet, the 2012 *AMS Information Statement on Climate Change,* 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 Climate Energy Model*** (**AMS CCEM**) to gain insight into how this happens.

Go to the course *RealTime Climate Portal* and in the Extras section, click on "AMS Conceptual Climate Energy Model", scroll down and click on "Run the CCEM Model". In *Investigation 1B* you made runs of the AMS CCEM when the imaginary planet had one atmosphere and when it had no atmosphere. You found that the number of energy units in the planet's climate system (planet's surface and atmosphere) was considerably higher when atmospheric CO_2 was present.

To review and confirm this finding, examine the planet again by setting the AMS CCEM's Sun's Energy setting at 100%, Albedo at 0%, Atmospheric CO_2 at None, Initial Energy at 1, Cycles at 100, and Mode at Introductory. Click on "RUN" and watch the paths of individual energy units. Note that energy units at the planet's surface will, in the subsequent moves, have a 50-50 chance of remaining at the surface or escaping to space.

12. Note the data immediately above the graph at the end of the run. They show that the mean (average) amount of energy in the climate system from the 51^{st} to 100^{th} cycle is ________ units. [Note: Statistical calculations in the AMS CCEM are based on data after the 50^{th} cycle when the model is assumed to have reached an equilibrium state. This will be described in greater detail later in the course.]

    [ ] 0.5
    [ ] 1.0
    [ ] 2.0

13. Change only the model's Atmospheric CO_2 setting from None to Current (1x), and run the model. This setting results in the mean amount of energy in the planet's climate system from the 51^{st} and 100^{th} cycle being ________. Note the subsequent moves of

energy units temporarily residing in the atmosphere. During the next cycle of play, they will either return to the plant's surface or be emitted to space.

[ ] 4.3
[ ] 5.6
[ ] 6.8

14. Finally, change only the Atmospheric CO_2 setting from Current (1x) to Future (2x). Note that the doubling of the atmospheric CO_2 is represented by two colored layers, one aqua and one light blue. Energy units must make at least one stop in each layer before being emitted to space. Run the model. This setting results in the mean amount of energy in the planet's climate system from the 51st and 100th cycle being ________.

[ ] 4.3
[ ] 5.6
[ ] 11.1

15. The change you observed implies that changing the amount of atmospheric carbon dioxide brings about a change in the amount of energy in the planet's climate system. Increasing atmospheric carbon dioxide (or other heat-trapping gases) in a planet's atmosphere results in ________ 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.

[ ] lower
[ ] no change in
[ ] higher

Summary:

The observational record definitively shows that global climate change is occurring with trends over the past several decades toward higher temperatures and rising sea level. The observational record shows that, while trending upward, these changes show considerable variability (ups and downs) and are not uniform around the planet. The AMS CCEM 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 USGCRP NCA3 publication provides a comprehensive report of the climate-related changes that have already been observed globally and in the United States. NCA3 focuses on climate change and its impacts on the United States, particularly in terms of climate change by sector (water resources, energy supply and use, transportation, agriculture, ecosystems, human health and society) and by regional climate change impacts (e.g., northeast, southwest, coasts). NCA3 is the prime reference employed directly, and indirectly via the *Climate Resilience Toolkit*, in *Current Climate Studies* segments.

Instructions for Communications with Mentor:

Transmit this week's work to your LIT mentor by Monday, 19 September 2016, or as coordinated with your mentor. Include:

1. **Chapter Progress Response Form** from the *Study Guide* or the *RealTime Climate Portal* website.
2. **Investigations Answer Form** for 3A and 3B from the *Study Guide* or *RealTime Climate Portal* website.
3. **Current Climate Studies Answer Form** from *RealTime Climate Portal* website