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Global Warming or Global Cooling - What's Next?

Global surface temperatures have been in a general warming trend the entire length of the instrumental record and much of the warming has been attributed to anthropogenic forcings. Though the record extends at least as far back as the mid-nineteenth century, most of the observed warming has occurred in the most recent 40 years (IPCC 2007). Still, global temperatures have failed to make new highs since 1998 and trend analysis shows that the warming trend has ceased and has been essentially zero since 1998 (0.13 ±0.13°F). Meanwhile computer models, utilized by IPCC for global temperature projections, predicted that temperatures should have warmed by 0.36°F. What is the physical basis for the discrepancy between the observed global temperatures and the simulated temperatures from global climate models (GCMs)?

There are several theories as to the physical mechanism behind the "plateau-ing" of global temperatures. The most generalized theory is that of natural variability. Global temperatures are not constant; they vary on the order of a few tenths of a degree per year. Over the course of a century, global temperatures can fluctuate up to 1.5°F. Therefore, the 0.2-0.3°F difference between the expected warming trend and the observed flat trend falls within the natural envelope of decadal variability. Furthermore, careful analysis of the GCMs used in climate projections show multi-year periods of cooling consistent with the recent observed temperature trends. However, analysis of many GCM simulations limit cooling or non-warming periods to at most 15 years. Besides natural variability, other theories attribute the cessation in warming to variability in specific boundary forcings of the climate. One theory is that solar variability is counteracting the warming. Solar variability is at its lowest level in more than a century; the drop in solar activity has effectively canceled the warming effect from greenhouse gases. A second theory is that a twen-y year increasing trend in autumn snow cover in Eurasia has contributed to an increase in stratosphere-troposphere coupling forcing, a hemispheric pattern that preferentially cools the Northern Hemisphere land masses in winter. Finally, a third theory attributes cooling temperatures to a weakening of the Atlantic Meridional Overturning Circulation (MOC), which cools the North Atlantic sector offsetting warming temperatures due to anthropogenic forcings.

So what will temperatures do in the coming decade? Will they return to the strong warming trend observed in the latter half of the twentieth century or will global temperatures remain below the all time high temperature mark recorded in 1998? We should find out soon. Based on arguments of natural variability and analysis of GCM simulations, the cessation of a warming trend can last a few years longer at most. Thus, it is inevitable that the global warming trend will restart in the coming decade. Solar variability has a timescale of 11 years so the current "cool" cycle of solar variability is coming to an end and should reverse in the coming decade. Snow cover and stratosphere-troposphere coupling also has a natural quasi-decadal cycle so that too may see a trend reversal that would contribute to rebounding temperatures, though the natural cycle itself may be perturbed by global warming and may deviate from its natural cycle. That leaves the Atlantic MOC, which, in contrast to the other aforementioned theories, is predicted to continue to contribute to cooling temperatures in the coming decade. Therefore, based on the scientific consensus, temperatures should resume warming in the coming decade. However, the cooling of the past decade was not predicted by GCMs and has surprised scientists. More surprises are possible, if not probable, in the coming decade.

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In This Issue

The United Nations Climate Conference will be held from December 7-18, 2009 in Denmark. The goal is to pass a binding global climate treaty that mandates a reduction in carbon emissions from both industrialized and developing countries. In this issue of AER Insight, as the world's governments prepare to focus on funding scientific research on climate change to legislating policy that mitigates predicted climate change, we provide scientific context and pertinent ongoing research results as background to the impending political wrangling on climate change.

Many are skeptical of man-made global warming. In the Northeast, residents were still waiting for summer to arrive when it started snowing! If the planet is getting so warm, how come it is so cold outside? We provide answers to what is behind the recent cold spell (including a more detailed look at solar variability) and what we can expect in the years to come; global warming or more cooling. Carbon dioxide is the best known GHG associated with global warming but, what are the other greenhouse gases emitted by humans, and what is the relative contribution of the GHG's to global warming?

Legislation is being discussed in Congress to guarantee our compliance in meeting lower emission standards. We discuss Cap and Trade, a bill that passed the House in anticipation of a global treaty on climate change. What future technologies can be developed to ameliorate the worst consequences of a warming planet? We discuss the new scientific field of geoengineering the Earth's climate and whether we can effectivly control the Earth's thermostat to keep global temperatures steady.

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Wind On The Water: Who Is Driving The Climate?

The global atmosphere and ocean both play key roles in Earth's evolving climate. The atmosphere is like the hare and the ocean is like the tortoise. When presented with changing conditions, the atmosphere responds quickly – think of the changing seasons, driven by variation in sunlight received by the Earth. In contrast, parts of the ocean system respond slowly to change, even holding the memory of past events for hundreds of years in the deep ocean. Near the surface, however, the ocean is as responsive and dynamic as the atmosphere, running neck in neck with each other, vying for influence.

AER, in collaboration with NASA climate programs, has developed a new cross-calibrated, multiplatform (CCMP) ocean surface wind product with wide-ranging research applications in meteorology and oceanography. The CCMP products are the result of combining observations from ten satellites that monitor winds over the world oceans. The CCMP products have global ocean coverage (except for the Arctic Ocean) with 25-kilometer resolution every 6 hours for more than 20 years, beginning in July 1987. The winds are combined using a variational method developed at AER[1]. The CCMP products are an extension of NASA-supported work[2] to combine ocean surface wind data from SSM/I instruments in the 1990's. CCMP products are available for download from the Physical Oceanography Distributed Active Archive Center (PO.DACC) at NASA's Jet Propulsion Laboratory (http://podaac.jpl.nasa.gov/DATA_CATALOG/ccmpinfo.html).

Since the ocean and atmosphere influence each other, it is difficult to determine which has the greater influence on the climate. The interchange between ocean and atmosphere at the ocean surface is played out in today's climate models. These models of the Earth system can use the CCMP data to produce simulations of the climate with more fidelity and will help untangle the influence of ocean and atmosphere. The period of 1987 to the present represents only a small slice of time in the evolution of Earth's climate, but with a more accurate depiction of the global ocean surface winds in CCMP, furthering our understanding of atmosphere/ocean interplay is possible. This may also provide valuable insight into the future direction of Earth's climate, since the relationship between ocean and atmosphere is pivotal within the climate system.

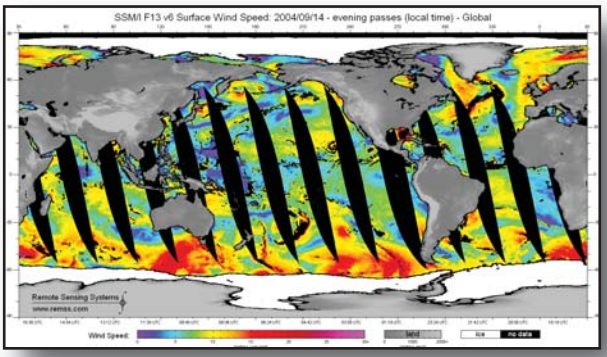

Fig 1. Wind speed coverage for one day of the ascending passes for the SSMI F13 instrument. This image and all the satellite ocean surface wind data we use are from Remote Sensing Systems (RSS, Santa Rosa, Calif.; http://www.remss.com/). Note that only half of the F13 data for September 14, 2004 is shown.

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Cap & Trade Legislation: Where Does it Stand?

This past June the US House of Representatives passed cap and trade legislation that would place limits on the emissions of greenhouse gases that cause global warming. Recently Senators John Kerry (D-Mass.) and Barbara Boxer (D-Calif.) unveiled the Senate version, formally titled the "Clean Energy Jobs and Americans Power Act" which requires a 20% reduction in greenhouse gas emissions by 2020. This is a more ambitious plan than the house version which requires a 17% reduction in emissions over the same time period. Both versions of the bill require an 83% reduction in emissions by 2050.

Under cap and trade, the government would place a limit or cap on the amount of greenhouse gasses refineries and power plants release into the atmosphere. Each company would have to purchase emissions permits at auction that allow them to emit a fixed amount of pollution into the atmosphere. Companies that release less than their emission allowance and come under the cap can sell/trade their credits to other companies that emit more pollution. The goal is to create a financial incentive for companies to implement pollution reducing technologies in order to comply with increasingly stringent requirements on greenhouse gas emissions.

Passing cap and trade legislation through the Senate is going to be an uphill battle. A number of moderate Democrats from energy producing states, where this legislation will hit their constituents hard, are troubled with the language in the bill. They fear the alternative, a national tax on energy, will make the U.S. less competitive overseas. Others in the party favor dropping the cap and trade from any climate change bill, preferring legislation that focuses on renewable energy alternatives. On the other side of the floor, a majority of Republicans oppose the Bill fearing that it will suppress economic recovery by increasing energy prices, unemployment and the tax burden on businesses and families across America.

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How Greenhouse Gas Impacts Climate Change

While carbon dioxide (CO_2) is often the focus of the human-induced climate change debate in popular media, other gases also play a role in heating the atmosphere. In particular, methane (CH_4), nitrous oxide (N_2O) and sulfur hexafluoride (SF_6) are key contributors to global warming even though they represent only a small fraction of the atmosphere. One measure of their effectiveness on heating the atmosphere is their "global warming potential" (GWP), a relative scale relating how much a particular gas is estimated to contribute to global warming as compared to CO_2. Over a 100-year timeframe, the global warming potential of CH_4 is over 20 times that of CO_2, N_2O and has a GWP over 300 times that of CO_2 and SF_6 has a GWP of nearly 23,000. These gases have both natural and anthropogenic sources and developing public policy for reducing their concentrations depends on a thorough understanding of sources and sinks for each. For example, the concentrations of atmospheric CH_4 could increase in years to come given the acceleration of CH_4-producing anthropogenic activities. The CH_4 concentrations could also increase due to the natural sources, such as changes in wetlands, the release of CH_4 from thawing permafrost, and the susceptibility of CH_4-hydrates to release from the ocean floor with rising seawater temperatures.

In order to quantify the contribution of these gases to global warming, it is important to understand the distribution of their sources and sinks. AER has developed a number of tools and techniques to address these science questions. In particular, we have developed a regional atmospheric transport model that, coupled with atmospheric trace gas measurements from in situ and aircraft platforms, has been used to quantify the fluxes of greenhouse gas sources [Kort et al., 2008; Zhao et al., 2009]. AER is also an active participant in several satellite-based remote sensing missions that can provide measurements of greenhouse gases. These include the NASA TES and AIRS instruments, the European IASI instrument, and the Japanese GOSAT. With these projects and tools, AER continues to be at the forefront of atmospheric measurements and modeling for better understanding of global climate change.

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Geoengineering the Climate

What controls the Earth's climate? It is a combination of external forcing factors and the characteristics of the Earth's climate system. The Earth's climate system includes the atmosphere, ocean, ice sheets and glaciers, soil, and ecosystems. All these go through cycles and changes over time scales of decades and longer. Some of the changes are due to the chaotic nature of these systems. Mathematically a chaotic system is extremely sensitive to small changes in "initial conditions." In practice, such systems are also very sensitive to any change in external forcing. Any small external change nudges the chaotic system slightly off course, creating a small change in the current conditions, which are exactly the initial conditions for the future.

Humans have been nudging the climate system since agricultural uses of land started to significantly change the Earth's surface characteristics. As population and technology have increased, our nudges have grown stronger. Certainly we have been adding carbon dioxide (CO_2) and other greenhouse gases (GHGs) to the atmosphere at an accelerating rate.

Responses to climate change are often described as mitigation or adaptation. Mitigation responses reduce the amount of GHGs in the atmosphere. Adaptation responses change the way we do business to adapt to a changing climate. A third response is geoengineering. Geoengineering includes methods to remove CO_2 and other GHGs from the atmosphere and to reduce the amount of sunlight that warms the Earth. Methods to remove CO_2 are considered safer as these would effectively cancel society's addition of CO_2, but all would be relatively slow acting, taking decades to make a noticeable difference. Methods to manage solar radiation would act more quickly, perhaps in a year or two, but might have unforeseen consequences.

Geoengineering is usually thought of as purposeful activities, but it must be recognized that mankind is now conducting a huge geoengineering experiment inadvertently by adding GHGs to the atmosphere. Certainly it is prudent to reduce emissions and slow down this experiment. It is also prudent to better understand the perils and potentials of purposeful geoengineering.

To learn more, an excellent, well written report by the Royal Society titled "Geoengineering the Environment" was released in September 2009.
http://royalsociety.org/geoengineeringclimate/

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Solar Variability and Global Warming

The contribution of solar variability to climate change on Earth has been a topic of debate and investigation for centuries. Recent detailed measurements from instruments on multiple NASA satellites show that the total energy emitted by the Sun that annually reaches the Earth varies by about 0.1% during the 11-year solar sunspot cycle. This is tiny compared to seasonal variations in sunshine at all latitudes, and it is much less than differences in sunshine during the year by about 3% due to the eccentricity of Earth's orbit (Earth is closer to the Sun in January than in July). The greenhouse effect is also much larger; the radiative forcing at the surface due to increases in carbon dioxide alone since 1750 is ten times larger than the radiative forcing from solar changes over the same time.

While the effect of solar variations on Earth's upper atmosphere can be considerable, especially during brief high-energy bursts, few mechanisms have been proposed that can transfer small decadal solar variability from space to atmospheric changes at the surface. One possible mechanism may derive from the fact that solar variations are largest in the ultraviolet part of the solar spectrum, which may unevenly alter the absorption of sunlight by ozone and consequently the heating and circulation in the stratosphere. AER scientists are developing radiation models with a very high level of accuracy in order to simulate precisely such small radiative effects.

Are decadal solar variations apparent in surface temperature measurements? The Blue Hill Observatory in Milton, MA maintains one of the most accurate and self-consistent climate records in the country. Annual and January mean temperatures at Blue Hill do not correlate well with the sunspot number, which is a measure of the 11-year solar cycle. This suggests that, at least at this location, solar variations are at most only a small contributing factor to the observed warming over the last century.

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AER People in the News

AER's reputation as a leader in climate change and weather/environmental research generated strong media interest which has solidified our reputation as national thought leaders on the influence of the climate and environment on commerce and society. Following is a quick snapshot of some of AER's recent media coverage: **Harpers Magazine**, October 2009 issue: Disaster Aversion, The Quest to Control Hurricanes (featuring Dr. Ross Hoffman); **CNBC Consumer Nation Blog** on October 7th, 2009: Weather Impact on September Retail Sales – "Why These Retailers May Beat Sales Estimates Tomorrow"; **USA Today** on October 9th, 2009 – "Retail Sales Hint at 'Less Bad' Holidays; Chilly weather may have spurred September shoppers"; **Fox Business News** on October 13th, 2009 with Dagan McDowell and Brian Sullivan: Managing Climate Change Risk; **Philadelphia Inquirer**, on October 15th, 2009: Interview with Dr. Judah Cohen; **Fox Business News**: October 15th, 2009 – Managing Climate Risk Part 2; **CNBC Squawk on the Street** with Mark Haines and Melissa Lee, October 21st, 2009 -- Weather Impacts And Risks On The 2009 Holiday Season/Winter; **CNBC Consumer Nation**, October 27th, 2009 -- "Five Reasons US Retailers May Have a Jollier Holiday This Year" **To read the articles or view the clips go to http://www.aer.com/news/inTheNews/index.html.**

Recent Posters, Publications & Presentations

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