Climate Outlook to 2030

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Abstract
Our forecast for global average temperature to 2030 has been updated for the progression of Solar Cycle 23 and the contribution that will be made by increased carbon dioxide in the atmosphere. The increased length of Solar Cycle 23 supports the view that Solar Cycle 24 will be weak, with the consequence of increased certainty that that there will be a global average temperature decline in the range of 1° to 2° C for the forecast period. The projected increase of 40 ppm in atmospheric carbon dioxide to 2030 is calculated to contribute a global atmospheric temperature increase of 0.04°C. The anthropogenic contribution to climate change over the forecast period will be insignificant relative to natural cyclic variation.

Introduction

There are numerous published correlations of past solar activity with the historic climate record. These studies include correlations of the record of the ice ages with the Be^{10} record and detailed work on the 20th century temperature record undertaken by Friss-Christensen and Lassen (1991). These studies show that the Earth's climate moves in lockstep with solar activity. A number of solar physicists are now also predicting future solar activity, with a few of these predictions ranging out to beyond 2100.

Archibald (2006) used the calibration provided by the work on the historic record to make a prediction of the global climate response to Solar Cycles 24 and 25. The conclusion of that paper was that the low amplitudes projected for these two solar cycles by a number of well regarded solar physicists would result in a global atmospheric temperature decline of the order of 2°C. This temperature response would be similar to that of the Dalton Minimum from 1796 to 1820, a well documented period of low global temperatures caused the low amplitudes of Solar Cycles 5 and 6.

Progression of Solar Cycle 23

The average length of a solar cycle is 10.7 years. Solar Cycle 23 started in May 1996, rising to a peak of 120.9 in April 2000. For Solar Cycle 23 to be of average length, Solar Cycle 24 should have started in January 2007. The first sunspots of a new solar cycle appear usually at more than 20° latitude on the Sun's surface. According to the last couple of solar cycles, the first sunspots appear twelve to twenty months prior to the start of the new cycle. Apart from a few spotless magnetic dipoles, there have not been any reversed polarity sunspots with a latitude of more than 20° to the date of this paper. This means that Solar Cycle 24 is at least one year away, or the observational rule is wrong.

Large solar cycles usually arrive early and small solar cycles late. If the observation rule regarding the relationship between first sunspot of the new solar cycle and timing of solar minimum holds, then Solar Cycle 23 will be at least twelve years long. It also follows that the longer the delay to the month of solar minimum, the weaker the amplitude of Solar Cycle 24 is likely to be.

Friis-Christensen and Lassen (1991) found that, over the period 1850 to 1990, the length of the solar cycle correlated better with temperature than did solar cycle amplitude. This was confirmed for Armagh temperature data by Butler and Johnson (1996), who demonstrated a strong correlation of 0.5°C in mean annual temperature per one year of solar cycle length.

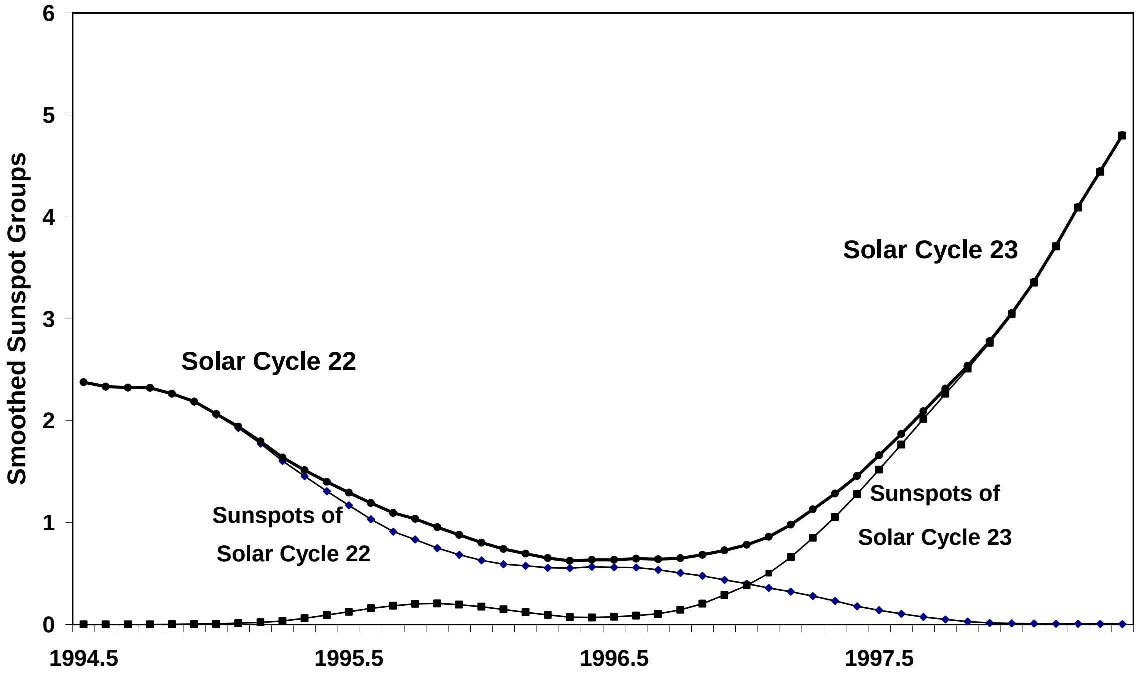

Figure 1: The Transition from Solar Cycle 22 to Solar Cycle 23
Data provided by J.Janssens, Belgian Solar Section

Solar minimum is the lowest point in the overlap between low latitude sunspots of the old cycle and high latitude sunspots with reversed polarity of the new cycle. This is illustrated by Figure 1 showing the transition from Solar Cycle 22 to Solar Cycle 23.

Amplitude of Solar Cycle 24

Figure 2 illustrates the range in predictions of the amplitude of Solar Cycle 24 amongst solar physicists. There are currently 24 published predictions, of which seven have been selected for this figure. The highest prediction is provided by Dikpati (2006) and the lowest by Clilverd (2006). Schatten (2004) has the longest track record in successfully predicting solar cycle amplitude, using the strength of the polar magnetic fields on the Sun in a solar dynamo model.

The significance of this spread of predictive values is that it equates to about a 2.0°C range in global average temperature. This range is significant in terms of the observed 0.6°C increase in global average temperature during the 20th century. Dikpati's forecast of 175 is similar to the Solar Cycle 19 peak of 190 in 1957. The late 1950s were a period of high temperatures before the 20 years of cooling to the mid-1970s, which was caused by the weak Solar Cycle 20. Clilverd's forecast of 42, if realised, would be the lowest for over 300 years.

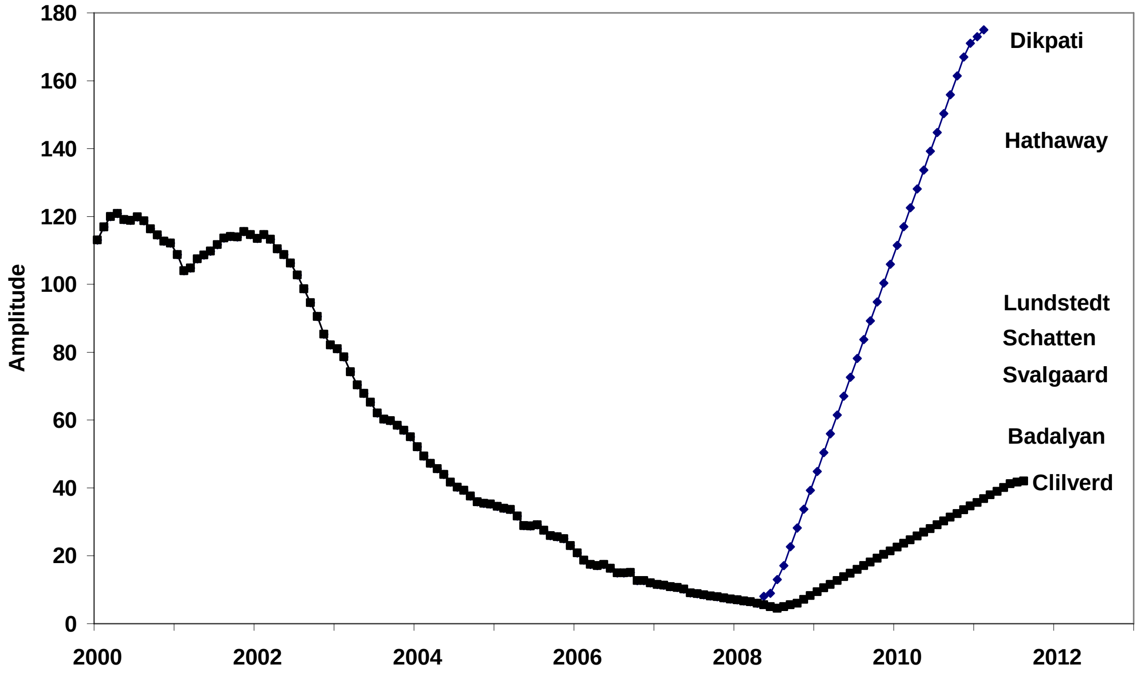

Figure 2: Predictions of the Amplitude of Solar Cycle 24

Temperature Effect of Increased Atmospheric Carbon Dioxide

The rate of annual increase in atmospheric carbon dioxide over the last 30 years has averaged 1.7 ppm. From the current level of 380 ppm, it is projected to rise to 420 ppm by 2030. Using the MODTRANS facility maintained by the University of Chicago, the relationship between atmospheric carbon dioxide content and increase in average global atmospheric temperature is shown in Figure 4.

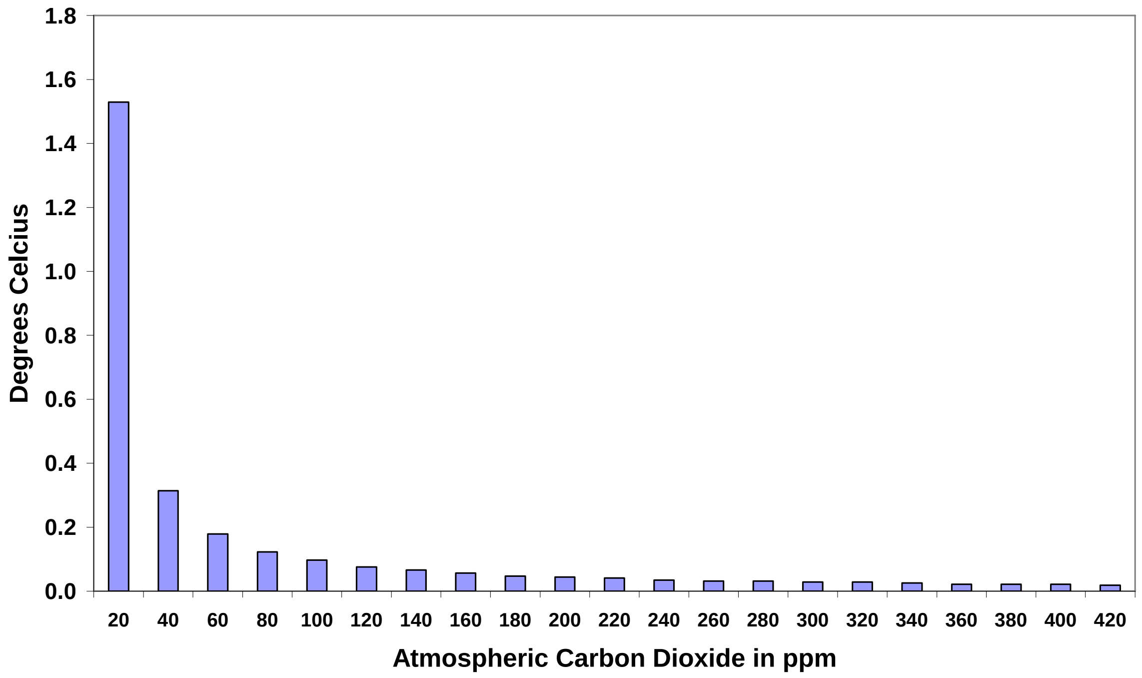

Figure 4: Increase in Atmospheric Temperature per 20 ppm Increment in Carbon Dioxide

The projected 40 ppm increase reduces emission from the stratosphere to space from 279.6 watts/m^2 to 279.2 watts/m^2. Using the temperature response demonstrated by Idso (1998) of 0.1°C per watt/m^2, this difference of 0.4 watts/m^2 equates to an increase in atmospheric temperature of 0.04°C. The effect of carbon dioxide on temperature is logarithmic and thus climate sensitivity decreases with increasing concentration. The first 20 ppm of carbon dioxide has a greater temperature effect than the next 400 ppm. Increasing the carbon dioxide content by a further 200 ppm to 620 ppm, projected by 2150, results in a further 0.16°C increase in atmospheric temperature.

The projected increase to 620 ppm is likely to be brought forward if Chinese economic expansion continues for the next ten years at the same rate that it has demonstrated over the last ten years. Figure 5 shows emissions of carbon to the atmosphere by the United States, Australia and China, with historic data to 2005 and a projection to 2020. Chinese emissions will overtake US emissions in 2009, and then double from the current level by 2016. Per capita emissions by the three countries will be equivalent by 2020.

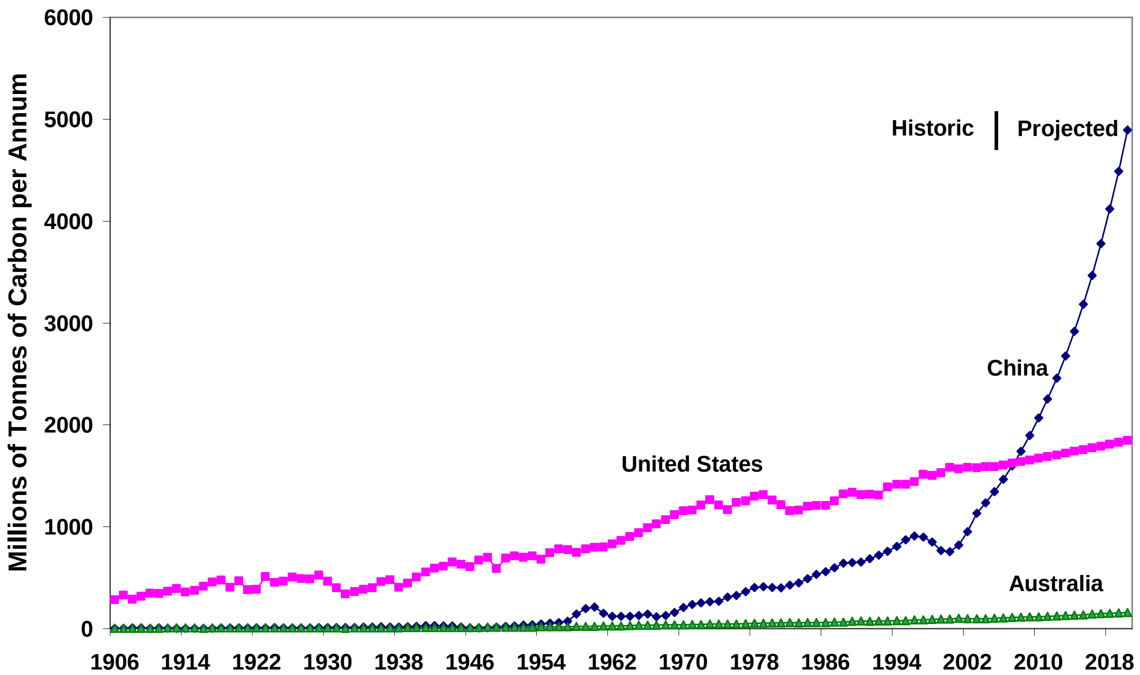

Figure 5: United States, Chinese and Australian Atmospheric Carbon Emissions for the Period 1906 to 2020

Data Source: Carbon Dioxide Information Analysis Center, United States Department of Energy

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