



A Survey of Climate Change since IPCC 4

1. Introduction

The 4th IPCC (Intergovernmental Panel on Climate Change) Report was issued in 2007 and preparations are now in progress for the 5th Report, which is scheduled to be issued in 2013. Activity in climate monitoring and climate modelling continues to expand worldwide. An increasing number of climate parameters are now being monitored by satellite. The resolution of the models is becoming finer as computer resources allow (the typical resolutions of global models at the times of the 1st, 2nd, 3rd and 4th IPCC Reports were 500km, 250km, 180km and 110km, respectively). Despite the advances in modelling, convergence towards a single accepted value of climate sensitivity (the equilibrium global mean temperature increase resulting from a hypothetical CO₂ doubling) between different modelling centres has not yet been achieved. The climate sensitivity estimated by the standard versions of the global models used in IPCC 2007 peaks in the range 2 to 4.5 °C, with some model versions giving values outside this range, on either side. There is little to indicate that convergence to a single accepted figure will be achieved in the near future.

The present survey looks mainly at climate trends as revealed by observations over the past few years.

2. Carbon Dioxide Increase

The upward trend in atmospheric CO₂ concentrations continues (see Fig. 1), having now reached 386 ppmv (parts per million by volume), an increase of 35 % over the pre-industrial value of 280 ppmv.

As a result of the economic recession, emissions in the EU and US decreased in 2008, by 3% and 2.8%, respectively (BAMS, 2009), but this decrease is not as yet reflected in the overall rate of increase of atmospheric concentration.

In addition to the climate implications, there is increasing concern about the rising level of ocean acidification resulting from CO₂ emissions. The impact of this on marine organisms and ecosystems remains poorly known. It is expected that this area will receive increased emphasis in the 2013 IPCC Report.

3. Changes in Average Temperatures

The global average temperature has *decreased* slightly over the past few years (see Fig. 2). This is regarded as due to the influence of natural variability superimposed on an underlying upward trend. The upward trend is expected to become evident again over the next few years, as the Pacific Ocean goes into an El Niño phase and Solar Cycle 24 gains strength (c.f. Section 4 on El Niño and Section 5 on the Solar Cycle).



A global map of mean temperature anomalies for 2008 (relative to the base period 1961-90) is shown in Fig. 3. It can be seen that the warm temperature anomalies are concentrated mainly over Northern Eurasia and the Arctic, with significant implications for the melting of Siberian permafrost and the release of methane, a strong greenhouse gas, into the atmosphere. The mean temperature over the Arctic is shown in Fig. 4, where it can be seen that a strong upward trend continues. Surface air temperature anomalies over the Arctic Ocean reached an unprecedented +4°C during October through December 2008 (c.f. Section 6 on Sea Ice).

4. El Niño/La Niña

The oscillation between El Niño (warm sea surface temperatures) and La Niña (cold sea surface temperatures) over the tropical Pacific Ocean over the last few decades is shown in Fig. 5. Warm El Niño events in 1982-83, 1987, and 1997-98 coincided with global warmth, but El Niño events were followed by cooler La Niña events as in 1985, 1988 and 1998-99. Nothing comparable to the El Niño event of 1998 has occurred since, but if previous patterns are repeated, a warm event should occur over the next few years. When added to the underlying warming trend due to CO₂ increase and the expected increase in solar output over the coming cycle, this should push the global average temperature to new records.

5. The Solar Cycle

The sun exhibits an approximately 11-year cycle (see Fig. 6) over which its energy output varies by a small but not negligible amount (approx. 0.1%). A solar minimum occurred in 2008 and the next solar cycle (known as Cycle 24) has been slow to get started. The recent period of relatively low solar activity is believed to have contributed about 0.1°C to the recent global cooling. It is predicted that the solar output will increase over the next few years and that the peak of Cycle 24 will occur in 2013.

6. Sea Ice

The most pronounced signal of climate change, in which greenhouse gas increases are believed to play a prominent role, is the decline of the Arctic sea ice over the past few decades (see Fig. 7). The ice extent reached a dramatic minimum in Sept 2007, at which time some polar scientists predicted that the summer ice cover in the Arctic would completely disappear within a couple of years. However, the ice extent recovered somewhat in 2008 and more so in 2009 (see Fig. 8). Despite this, the ice cover still remains more than 2 standard deviations below the long-term mean, and there are indications that the total ice volume (as distinct from the ice cover) is continually declining.

At the time of the 2007 minimum, it was believed that the unprecedented low ice cover was a manifestation of an unstable ice-albedo feedback (less ice leading to more solar radiation absorbed, leading to further warming and ice loss). It has been shown in the interim, however, that an anomalous wind pattern over the Arctic Ocean during the summer of 2007, which blew large amounts of ice into the Atlantic, contributed up to 30% of the ice retreat (Timmermans *et*



al., 2009). These authors take a more conservative view of the prospects of sea ice retreat than authors such as Peter Wadhams *et al.*, recently quoted in the news media, who predict that the Arctic will be ice-free during summer within a decade (see: www.catlin.com/cgl/media/press_releases/pr_2009/209-10-15/)

Meanwhile, the sea ice cover in the region of Antarctica has been *increasing* at a rate of about 1 percent per decade for the past 30 years, due to altered wind patterns (Turner *et al.*, 2009).

7. Land-based Ice

Unlike the melting of sea ice, which does not directly influence sea level, the melting of land-based ice does contribute directly to sea level rise. The melting of many glaciers along the margins of the Greenland and Antarctic ice sheets is accelerating (Pritchard *et al.*, 2009; Velicogna, I., 2009). Globally, ice losses are estimated to contribute $\sim 1.8 \text{ mm yr}^{-1}$ to sea level rise, the remainder of the total of 3.5 mm yr^{-1} being due to thermal expansion (see Section 8). Ice loss as a result of accelerated ice-sheet flow is so poorly understood that its potential contribution to sea level over the twenty-first century remains unpredictable.

8. Sea Level Rise

The global mean sea level, as measured by satellite, has been rising at a rate of 3.5mm/yr over the past 15 years (see Fig. 9, upper panel). Despite the reports of increased melting of land-based ice, the rate of rise is not observed to be accelerating. Variations in the rate of rise are strongly influenced by variations in El Niño/La Niña (see Fig. 9, lower panel). Once this variability is accounted for, the rate of sea level rise remains remarkably constant (Peterson *et al.*, 2009, p.S63-64).

9. Atlantic Hurricanes

Atlantic hurricane frequency is not increasing. The suspicion that an increase in the number of recorded Atlantic hurricanes during the past century is more apparent than real has been confirmed by Landsea *et al.* (2009). Their research has shown that with no satellites and a reliance on observations from ships, a large number of storms from the late 1800s to the 1950s would have been missed. The apparent increase in frequency of Atlantic hurricanes can now be attributed to more complete monitoring and better observations and analysis techniques.



10. Rainfall Trends in Ireland and the UK

In testimony given to the Oireachtas Joint Committee on Climate Change and Energy Security in June 2009 it was stated that “in winter in the north of the island, rainfall has increased by 70%, a huge amount and something the models for the future suggest will become more pronounced” (see <http://debates.oireachtas.ie/CommitteeMenu.aspx?Dail=30&Cid=CL> on 10-Jun-2009). This statement appears to have been based on the Malin Head record over the past hundred years (Sweeney *et al.*, 2002, Fig. 2.21). These data however, are inconsistent with the record at Armagh (see Fig. 10), where the winter rainfall curve over the past century shows no upward trend. An examination of the England and Wales precipitation from 1766 to the present (Fig. 11) also shows no definite trend.

11. Conclusion

It is frequently stated that the climatic change situation has become much more alarming since IPCC 2007. The evidence presented in this survey indicates that the underlying trends are continuing: increase in atmospheric CO₂ (+1.62ppm/year), increase in global average temperatures (+0.013 degrees / year), rise in sea level (+3.5 mm/year). Natural cyclical changes (sunspot activity; El Niño/La Niña) and normal climate variation superimpose short term and regional variability on these trends. However, global climate change is real and continuing at a steady pace.



Figures

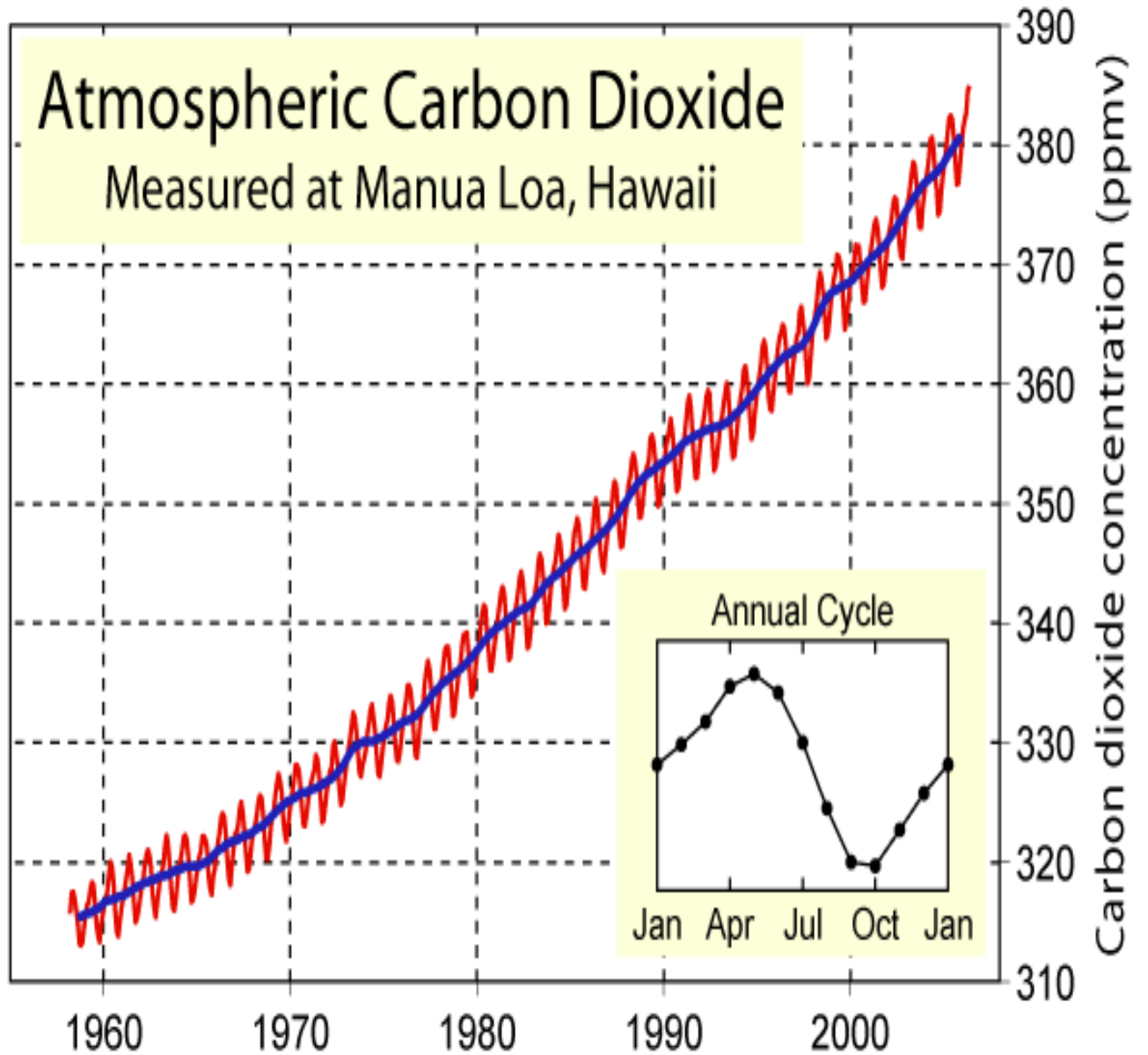


Figure 1. Atmospheric CO₂ concentration as measured at Mauna Loa, Hawaii, since 1957.

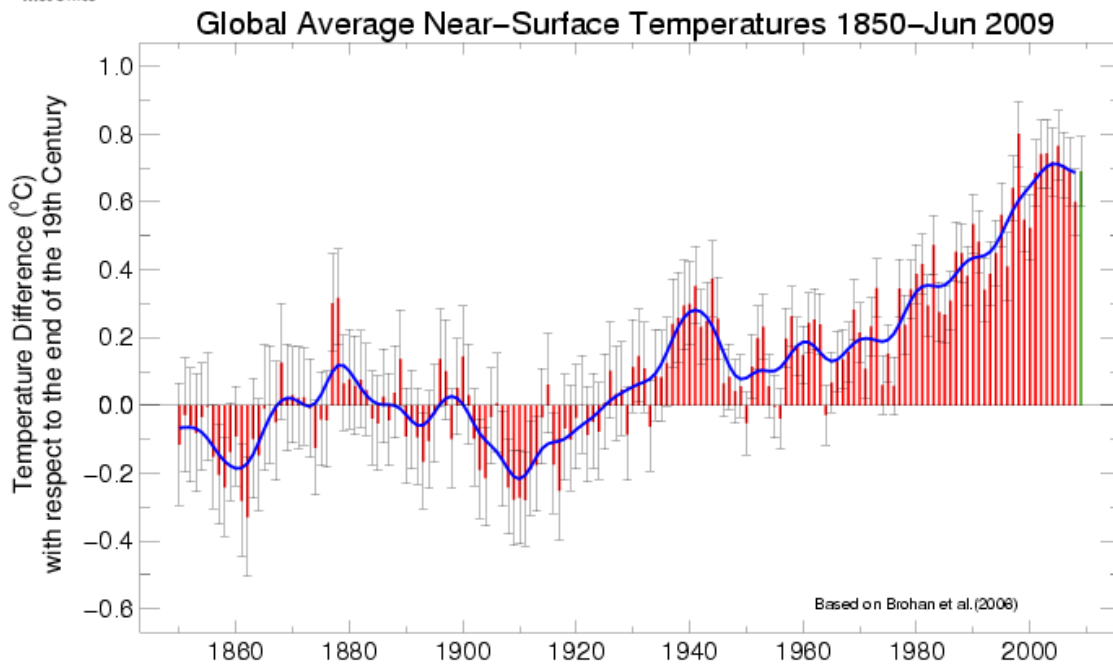


Figure 2. Global average near-surface temperature, 1850-2009. (UK Met Office).



Surface temperature

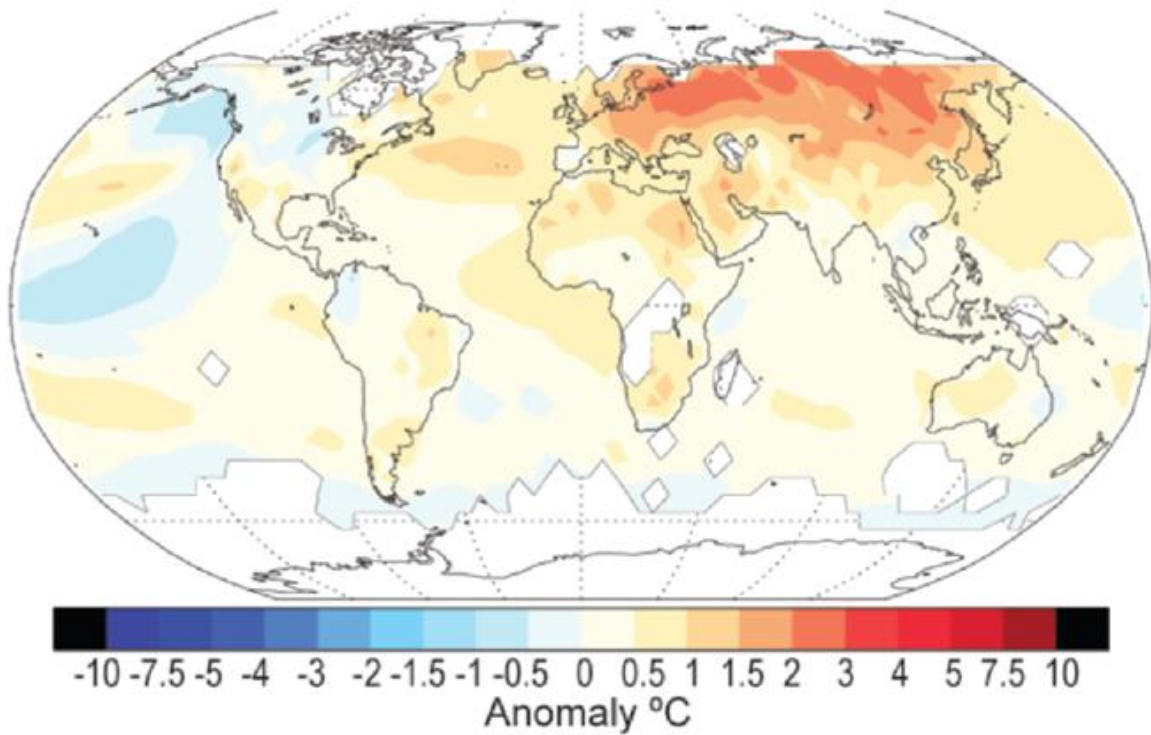


Figure 3. Map of global surface temperature anomaly 2008 (Peterson *et al.*, 2009, p. S18).

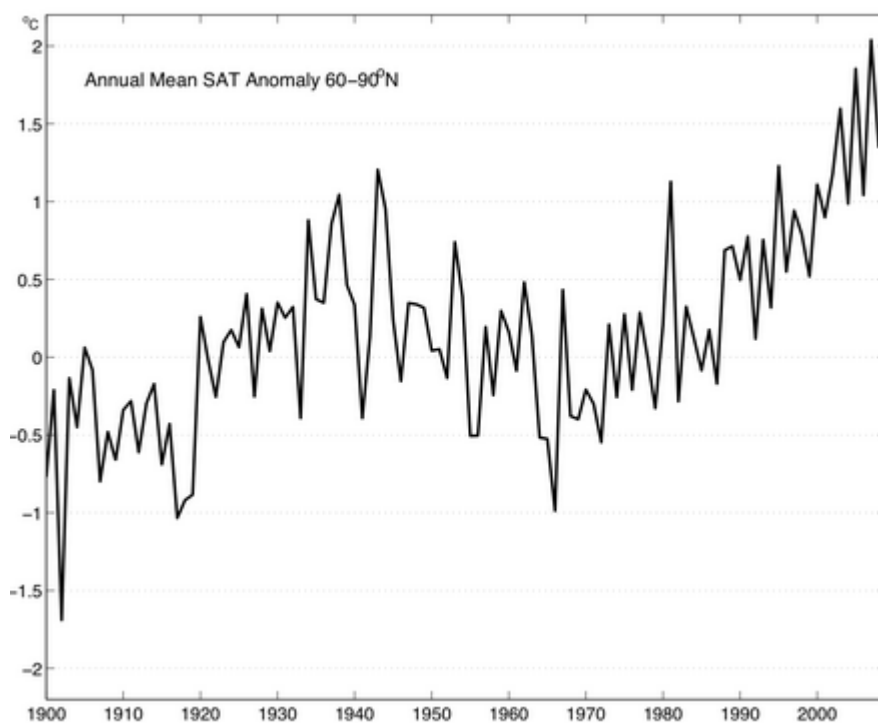


Figure 4. Arctic-wide annual averaged surface air temperature anomalies (60°–90°N) based on land stations north of 60°N relative to the 1961–90 mean. From the CRUTEM 3v dataset, (www.cru.uea.ac.uk/cru/data/temperature/).



Monthly Nino 3 region [150-90W, 5N-5S] average SST anomaly (°C) wrt 1961-90
HadISST1.1 1982-June 2009

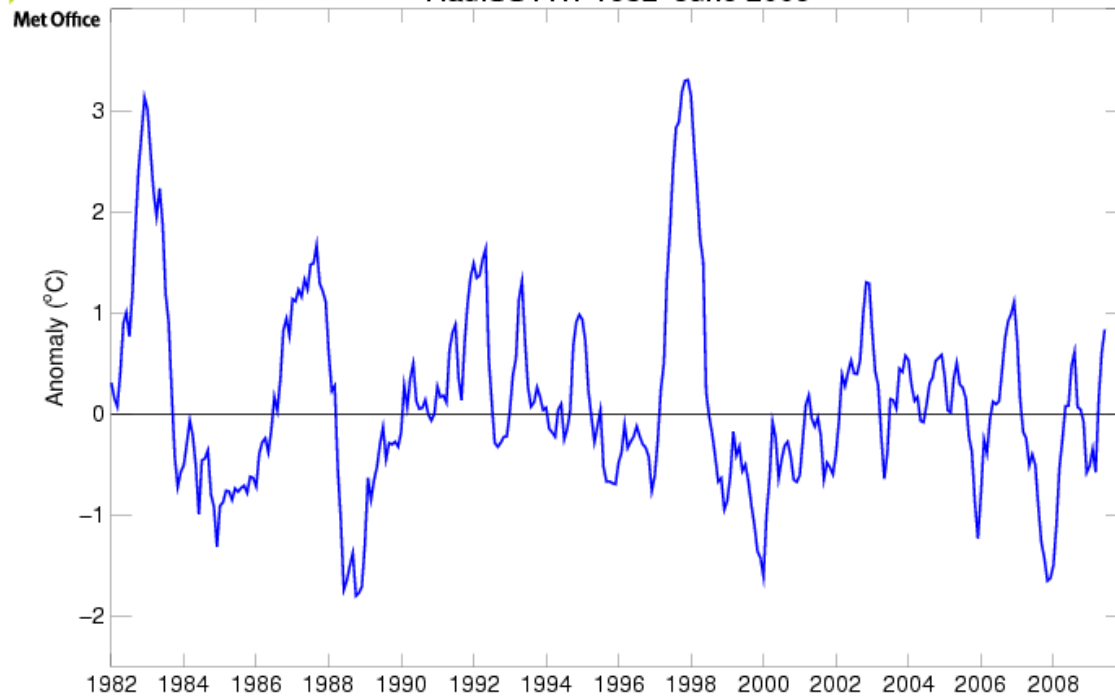


Figure 5. Pacific sea surface temperature variations associated with the El Niño/La Niña cycle (UK Met Office).

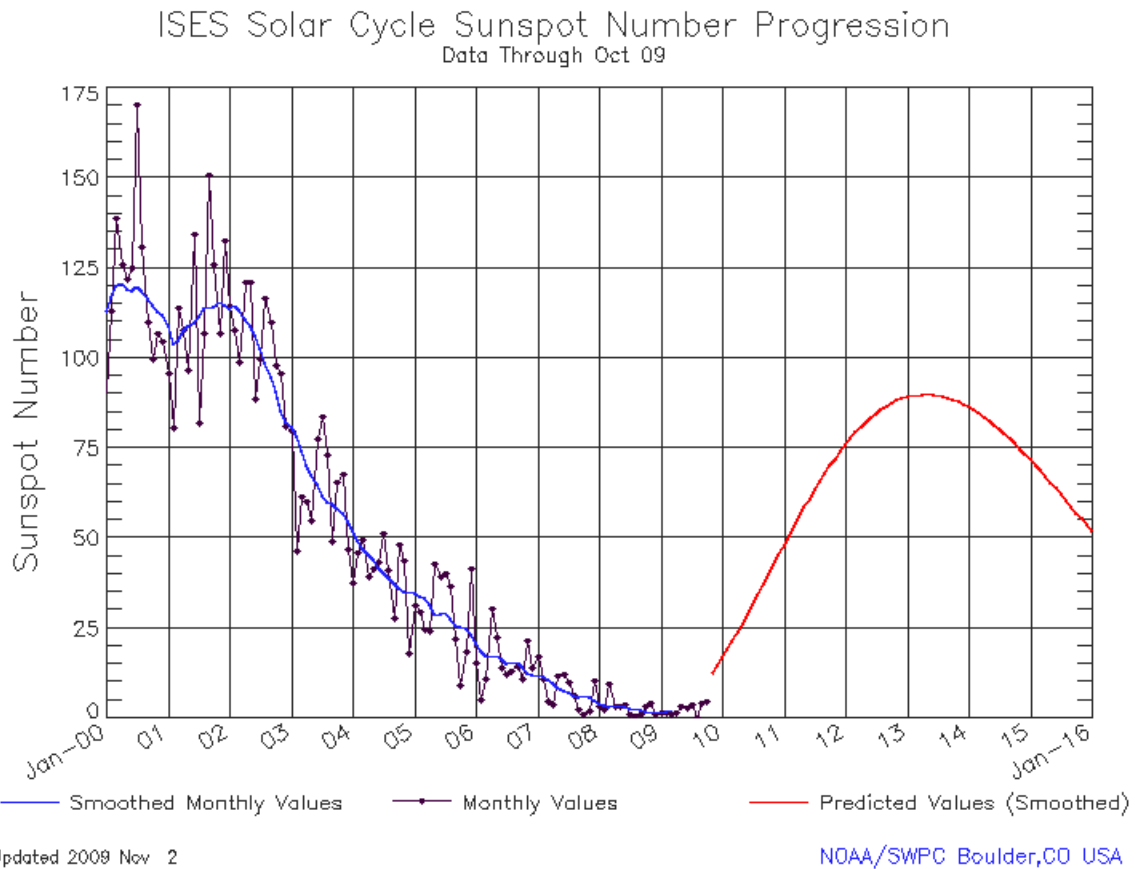


Figure 6. Solar cycle sunspot number, 2000-2009, with predicted values up to 2016 (NOAA/Space Weather Prediction Center (www.swpc.noaa.gov/index.html)).

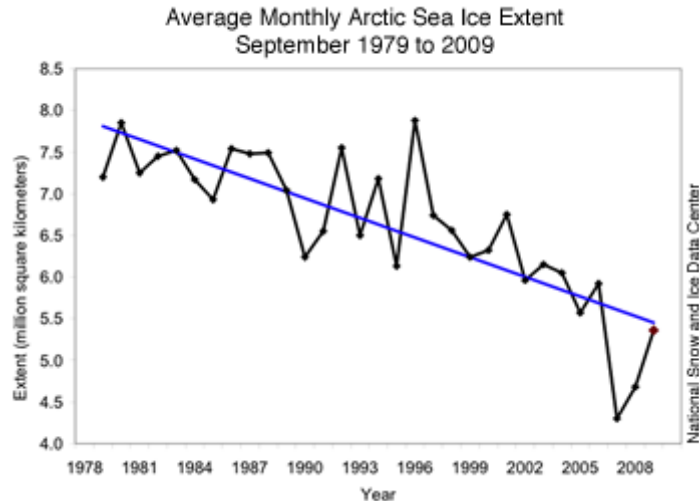


Figure 7. September ice extent from 1979 to 2009 shows a continued decline. The September rate of sea ice decline since 1979 has now increased to 11.2 percent per decade (Sea Ice Index data, US National Snow and Ice Data Center, http://nsidc.org/data/seaice_index/).

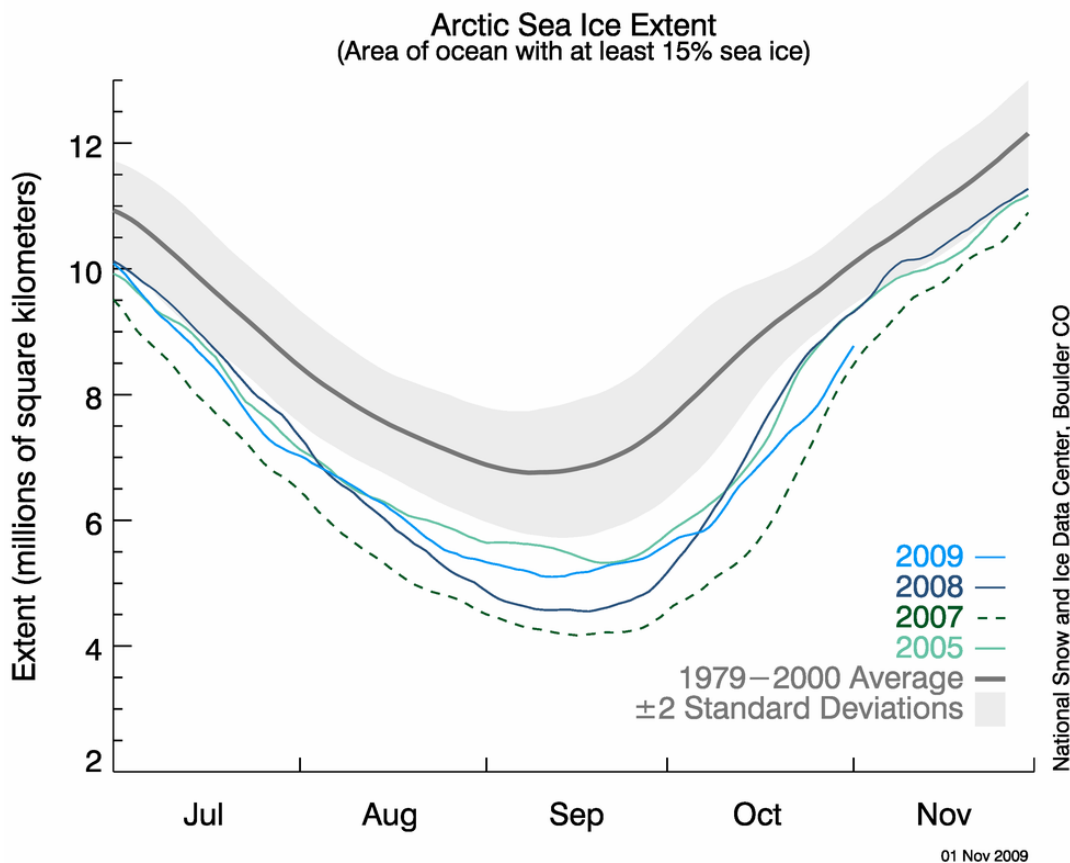


Figure 8. Arctic Sea Ice Extent from July to November during 2009 and previous years, from US National Snow and Ice Data Center.

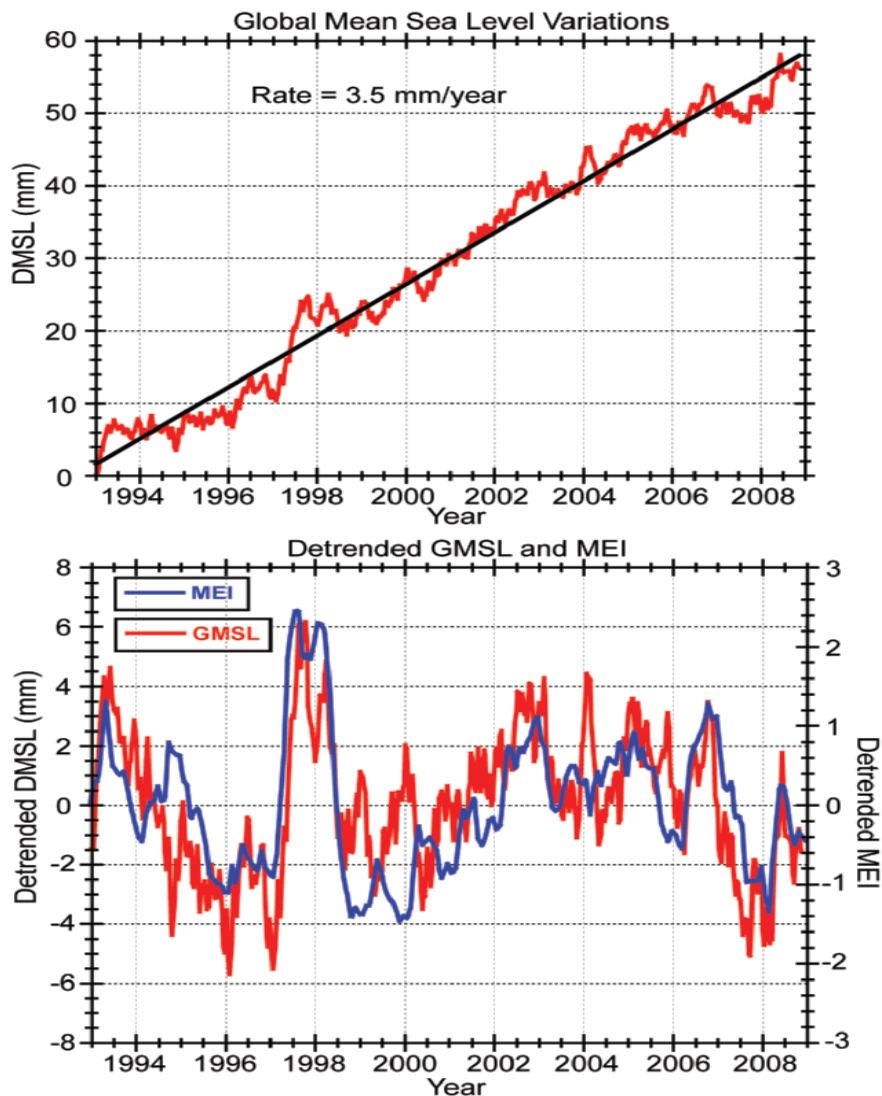


Figure 9. Global mean sea level (<http://podaac.jpl.nasa.gov/>). Upper panel: Monthly values (seasonal cycle removed) relative to a linear trend of 3.5mm/yr. Lower panel: Monthly values (linear trend removed, red) versus the Multivariate El Niño/La Niña Index, blue).

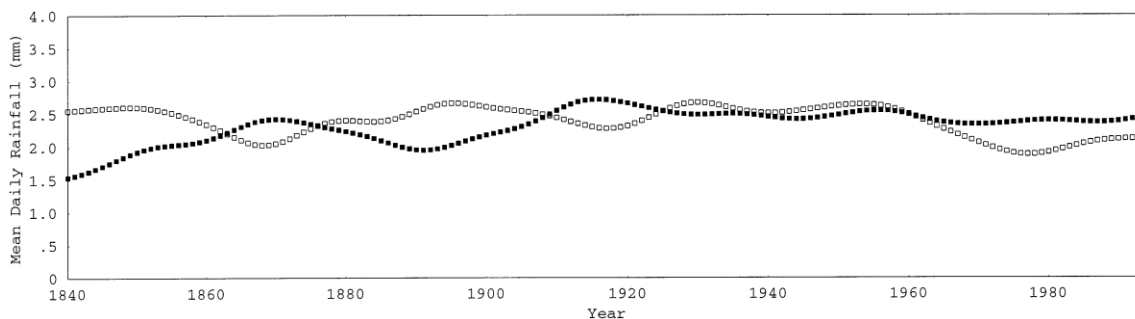


Figure 10. Mean daily rainfall at Armagh Observatory, 1838-1997 (Butler et al; 1998). Solid squares: winter. Open squares: summer.

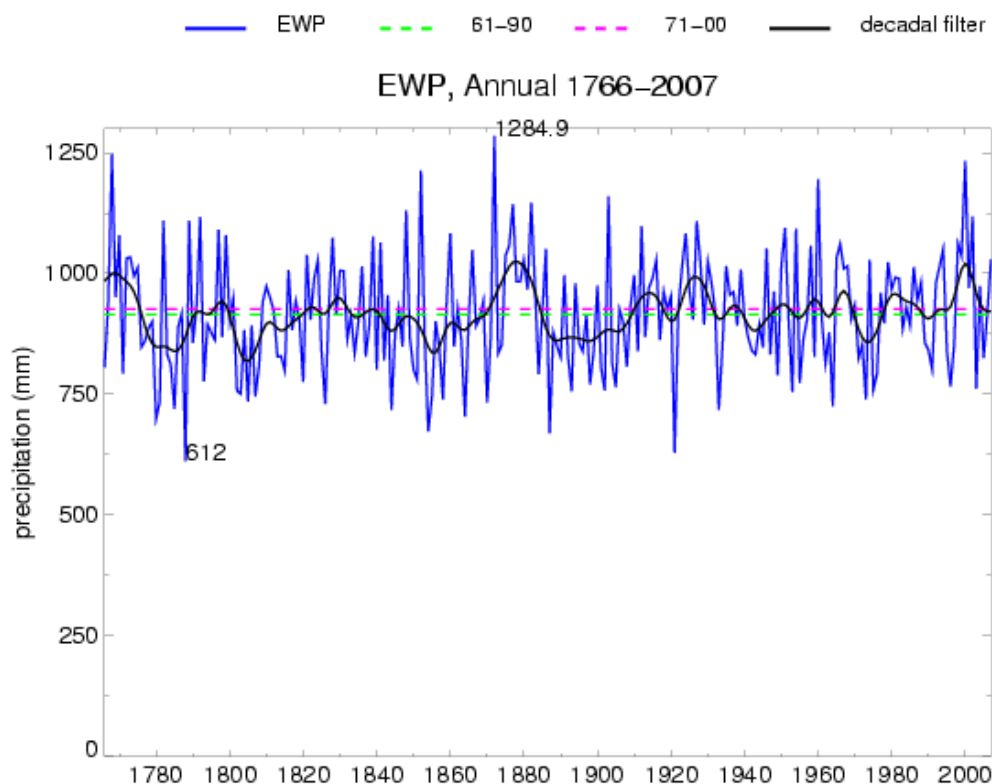


Figure 11. England and Wales Annual Precipitation 1766-2007 (www.metoffice.gov.uk/climatechange/science/monitoring/hadukp.html).



References

BAMS, 2009: Nowcast, *Bull. Amer. Meteor. Soc.*, **90**, 1059-1060.

C. J. Butler, A. D. S. Coughlin and D. T. Fee, 1998. Precipitation at Armagh Observatory 1838-1997. *Biology and Environment: Proceedings of the Royal Irish Academy*, **98B**, 123-140.

Landsea CW, Vecchi GA, Bengtsson L, Knutson TR., 2009. Impact of Duration Thresholds on Atlantic Tropical Cyclone Counts. *J. Climate*.
DOI: 10.1175/2009JCLI3034.1

Peterson, T.C. and M.O. Baringer, Eds., 2009: State of the Climate in 2008. *Bull. Amer. Meteor. Soc.*, **90**, S1-S196.

Pritchard, H.D., Arthern, R.J., Vaughan, D.G., and Edwards, L.A., 2009. Extensive dynamic thinning on the margins of the Greenland and Antarctic ice sheets. *Nature* (published online, 23 Sept 2009).

Sweeney, J., Donnelly, A., McElwain, L. and Jones, M., 2002. Climate Change Indicators for Ireland. Environmental Protection Agency.

Timmermans, M.-L., Francis, J., Proshutinsky, A. and Hamilton, L., 2009. Taking stock of Arctic sea ice and climate. *Bull. Amer. Meteor. Soc.*, **90**, 1351-1353.

Turner, J. *et al.*, 2009. Non-annular atmospheric circulation change induced by stratospheric ozone depletion and its role in the recent increase of Antarctic sea ice extent. *Geophys. Res. Lett.*, **36**, L08502.

Velicogna, I., 2009. Increasing rates of ice mass loss from the Greenland and Antarctic ice sheets revealed by GRACE, *Geophys. Res. Lett.*, **36**, L19503, doi:10.1029/2009GL040222.

This paper was prepared by Professor Ray Bates, University College, Dublin, a member of the Panel of Experts.