CLIMATE CHANGE

A Report
to the
General Assembly
of the
Presbyterian
Church of Australia
in NSW
July 2017

Introduction

The 2014 Assembly asked the committee to publish a resource paper on climate change. While this was a request that the committee had sought from Assembly, further reflection led the committee to two conclusions — first, that a discussion of climate change had to be set in a wider discussion of creation care; second that resource paper on either topic could not be produced without a clearer sense of the Assembly's views.

To that end, the committee prepared a report on Creation Care, which was received by the Assembly in July 2015. Assembly at that time also made several affirmations regarding creation care, amongst them that "a Christian perspective offers a basis for creation care missing from all other religious and philosophical positions in that it affirms the creation as the good gift of the Triune Creator", and it is "the responsibility of humanity before him to care for his gift and God's plan to restore his creation to his glory."

The Assembly also asked the committee to prepare a further discussion paper on the issues related to climate change.

That report was received by the 2017 Assembly and is reproduced on the following pages. It should be read in conjunction with the 2015 Report and the 2015 Assembly affirmations, which are available on the PCNSW website, and also the committee website.

Report to the Assembly of the Presbyterian Church of Australia in NSW and ACT

From The Gospel, Society and Culture Committee

November 2016

Climate Change

Introduction

This paper is not an attempt to explain the science of climate change in terms of a biblical worldview, rather it is a 'summary of the science' with an exhortation to humility. Many readers will, therefore, find reading it a somewhat uncomfortable exercise.

We suggest that the most helpful way to approach this paper is with a suspension of disbelief, and an interest in trying to understand what the society around us is saying about climate change. Imagine, if you will, a world where methodological naturalism works. Imagine scientists who love the truth and don't really have agendas to speak of. Ask, then, if what they are talking about makes sense in relation to itself?

Genuine complexities

The discussion

Climate science discussions tend to feel a bit chaotic. The primary reason for this is that there isn't really any such thing as "climate science" or a "climate scientist". There are physicists, biologists, botanists, ecologists, conservationists, oceanographers, upper atmosphere scientists, lower atmosphere scientists, meteorologists, geologists, astronomers, engineers, vulcanologists, and the list goes on. Each one of those scientists will have their own quite narrow specialisation. The astronomer might be interested in measuring solar irradiance and the oceanographer might be an expert in ocean surface temperature. Both of those specialties are related to the idea of climate change, so the two scientists might find themselves in a room at a climate change conference one day, being asked to explain how their specialty relates to the climate and why. Voila! They are now climate scientists engaged in climate science research.

In order for the astronomer to make a helpful contribution on solar irradiance, he needs to present his findings in all their gory astronomical detail, so that his own kind (who understand the technical details), can ask the right questions, the hard questions, and help him discern the truth in what he has observed. The astronomer has methodologies for measuring solar irradiance, assumptions that underlie those methodologies, and a large vocabulary of jargon surrounding the field – this means the oceanographer probably ought to sit quietly in the corner and trust that, whenever the astronomers make their pronouncement, it will be the best science to which we currently have access. Of course, the same applies in the other direction.

The reality of these discussions is somewhat different because the astronomer and the oceanographer are highly educated, scientifically minded people with a significant overlap in their training. This fact makes them *feel* like they understand each other better than they, in fact, do. This can lead to one making confident assertions about 'problems' in the other person's research, and public suspicion over results. From the outside, this kind of interaction makes it look as if there are genuine ambiguities about the research since all that is reported is that one scientist doubts the claim of another, which sounds like a fair fight. It seldom is.

Consider the frustration Christians experience when Richard Dawkins, a zoologist, declares that Jesus never existed, and quotes a professor of linguistics as his source, despite the fact that there is not a single, working ancient historian who denies the existence of Jesus. Academic versus academic may sound like a fair fight, but what about zoologist and linguist versus historian? Who are you more likely to trust, if you're asking a question about history? So it's not really a fair fight, because neither Richard Dawkins nor our linguistics professor has access to the data or methodologies of ancient history in order to make an informed determination for themselves. What the public hears, though, is that they should question whether Jesus existed.

There is also a certain amount of chaos at street level, as it were, stemming from a misunderstanding of some basic distinctions. You may have heard someone say something like, "Global warming?! Ha! We just had snow in Sydney!" Surprising as that might be, "snow in Sydney" is a description of weather, not climate. *Weather* is what happens today. *Climate* is the trend in what happens on that same day over the next 10 or 20 years. We also need to understand that the relatedness of various weather systems on the earth means that it is entirely reasonable for the earth to experience an overall warming while certain parts of the earth are cooling, even if that might only be temporary.

In any discussion, we must also be aware of our own commitments, special interests, and presuppositions about the world. We like to believe that we think independently, that we weigh matters carefully on the evidence, and that we are only interested in finding the truth, but Figure 1, below, from a Physics Today article in 2011[1] (in the article it is *Figure 3: Greenhouse Warming)* provides us with a cautionary tale. The chart shows how people think about climate change in relation to the total coal production of the nation in which they live. It turns out that the nations where the fewest people believe that climate is affected by humans are also the largest coal producers. The correlation is striking. This is confronting, but, as Christians interested in the truth, we should allow these results to interrogate those commitments that may be more cultural than motivated by love of God and neighbour.

Figure 1

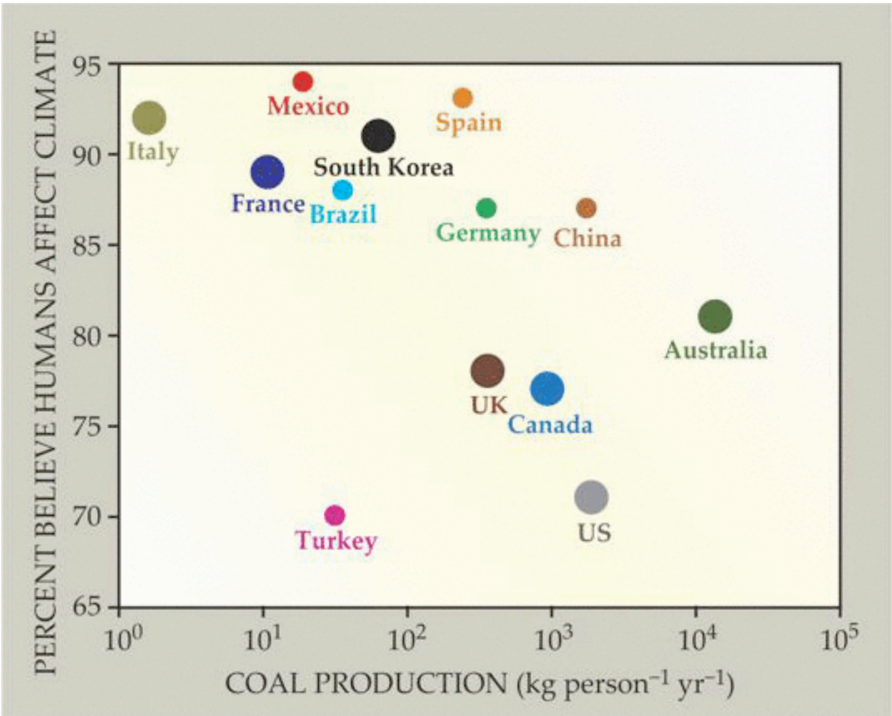


Figure 3. Greenhouse warming and its perceived policy implications challenge widely held libertarian ideals and provoke economic fears, as evidenced by the negative correlation between acceptance of anthropogenic climate change and coal production, especially among the wealthiest nations.[17] Large dots show nations where more than 80% of survey respondents had heard “a lot” or “some” about global warming; small dots show nations where 70–80% had. The vertical axis is the percentage of respondents who agree that humans affect climate, not necessarily who accept the greenhouse theory.

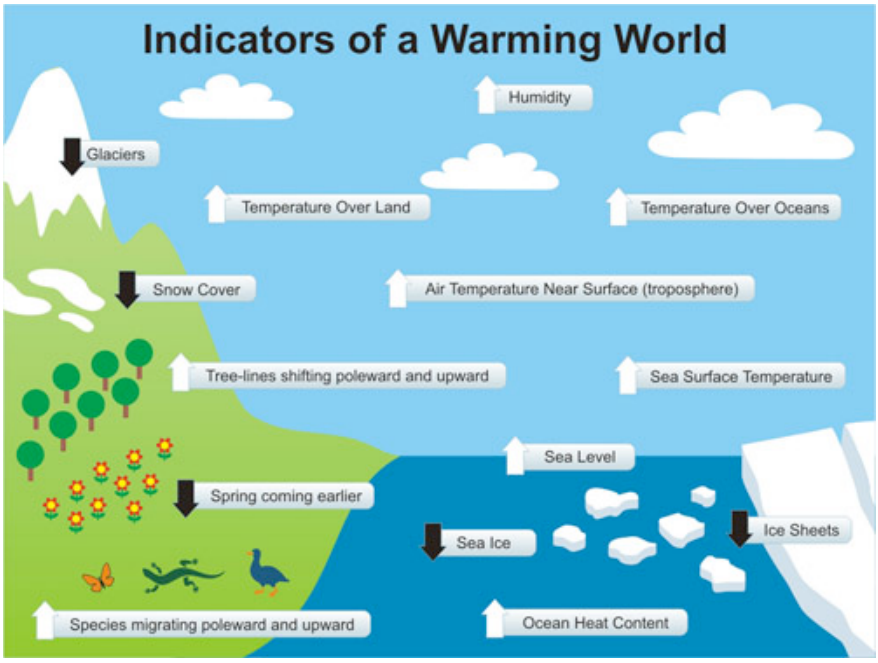
[1] Sherwood, S., “Science controversies past and present”, *Physcis Today*, **64**(10), 39-44 (2011)

The Science

The Science is also complex. Consider for example one of the significant factors in understanding climate trends: the measurement of Total Solar Irradiance (TSI). There have been four different satellites in operation at overlapping epochs over the past 40 years measuring the TSI. Even for solar astronomers, there is much hard work and careful consideration to be given in calibrating those measurements to one another, because they were made by different instruments representing different methodologies, yet all trying to measure the same number. Antarctic ice core measurements of temperature and atmospheric carbon concentrations is another complicated area where factors like the design of the drill used to extract the core needs to be considered in the final results. The Science is complicated, but not impossible, and with diligence, scientists are making progress in producing a reliable understanding of our climate.

As noted above, there are many different disciplines within Science producing data that is relevant to understanding the climate and changes in it over long timescales. Figure 2, below, gives an indication of the different streams of evidence being incorporated into an evaluation of the relatively simpler question of global warming.[2] The sheer number of disciplines involved is a major contributor to the complexity of the task, but the interconnectedness of the data adds another layer to the complexity. It would be fair to say that virtually everything that happens in our solar system will have some impact on the earth's climate, either in the short, medium, or long term: the orbit of the moon, changes in the irradiance of the sun, cosmic rays and aerosols seeding reflective clouds. It would also be fair to say that all of those things are connected in some way. Looking at Figure 1, we can imagine that sea level and the tree line might be relatively independent of each other, while the tree line and species migration are likely to be much more closely related. What are the feedback mechanisms between each of these streams of evidence? How do we account for that intra-feedback when evaluating the significance of any one type of data for understanding and predicting climate change?

Figure 2



[2] This graphic was accessed at http://www.skepticalscience.com/graphics.php?g=8 on 11/10/2016.

Every plant has a different Carbon storage capacity, which affects the calculation of how much Carbon we think is being deposited in the atmosphere. The author recently met a scientist at the cotton research station in Narrabri working on the Carbon storage potential of various fungi, and later, in Wollongong, a PhD student asking the same question of wetland ecosystems. These two encounters alone illustrate the complexity of the factors to be considered.

Indeed, the interconnectedness of all these systems provides the challenge for the one discipline that deserves the name Climate Science, namely, *climate modelling*. Scientists working in this field are the ones who build our understanding of how all these different systems work, taking into account, as best they can, the dependencies of each system on others, and trying to predict general climate trends into the future.

When the *climate modelling* discipline began, scientists knew very little about each individual system, and even less about the relationships between them. As a result, the models were unable to reproduce the past behaviour of the earth's climate, rendering them untrustworthy for predicting the future. The situation, however, is improving all the time. That's Science. We keep on learning new things and incorporating that new knowledge into models of how our world works. It's an exciting business.

The latest models are now able to reproduce, within the errors, the past climate trends on the earth. This is a welcome and extraordinary state of affairs that allows scientists to now predict for us the consequences of our actions into the future. We can predict that if we do A, then X will result. If we do B, then Y will result. If we do C, then Z will result. And so on. This is not now, nor ever will be, a precise science: X, Y, and Z are trends, not precise numbers, but we can, now better than ever before, place more firm boundaries on those trends, and give a believable range of numbers to work with.

Errors or mistakes?

Experimental ‘errors’ are variations in experimental measurements, either in *accuracy* (the difference between a measured value and the true value) or *precision* (the difference between two measured values, sometimes referred to as *repeatability* or *reproducibility*). No physical quantity can be measured with perfect precision or perfect accuracy. Experimental errors are inherently part of the measurement process.

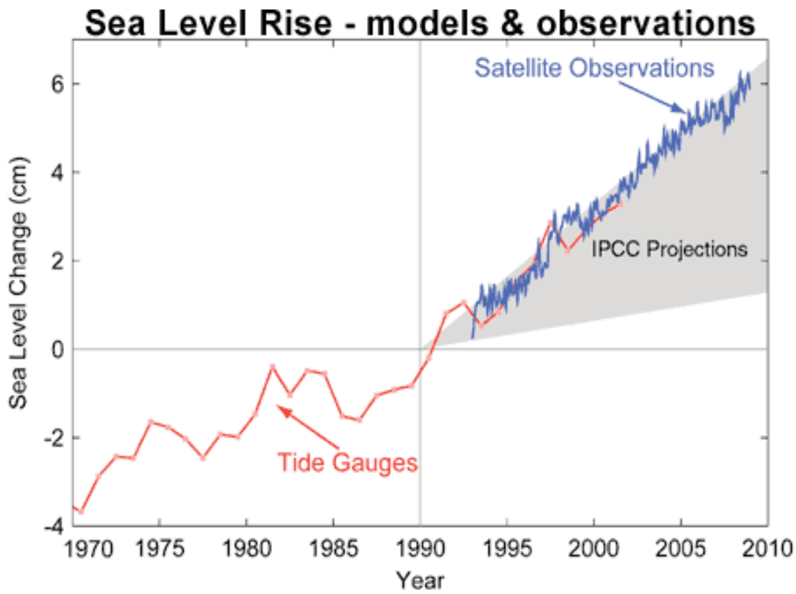
Systematic errors yield measurement results that repeatedly differ from the true value by the same amount. Such errors affect the accuracy of a result. They are not easy to detect, but once detected can be reduced by refining measurement technique or method. Examples of systematic errors include the faulty calibration of a measuring instrument, or parallax errors that come about because the scientist always reads the measurement scale from the same (wrong) angle.

Random errors affect the *precision* of a set of measurements. They arise out of unpredictable errors in the measurement process, and yield results that differ in varying amounts from the true value. Random errors can be analysed through statistical analysis, and confidence in the experimental results can be improved by refining the measurement technique and increasing the number of measurements made.

When scientists report the results of an experiment, an analysis of the ‘errors’ is included. This helps the reader to judge what level of confidence can be placed in the conclusions of the experiment.

Figure 3, below, shows one example of how the models are working on the subject of sea level rise.[3] The red line shows measurements from tide gauges and the blue line is measured from satellites. First of all, note that the independent observations match. That's a great start. Secondly, note that the observed data falls within the model predictions, in grey. The good news here is that Science is working and arriving at a point, within this field, where it can make meaningful predictions. Slowly, yet steadily, we are untying Gordian's Knot.

Figure 3



Observed sea level rise since 1970 from tide gauge data (red) and satellite measurements (blue) compared to model projections for 1990-2010 from the IPCC Third Assessment Report (grey band). Sea level rises mainly as a result of melting land ice and thermal expansion of ocean water as temperatures rise. Observed sea level is tracking at the upper range of the IPCC projections. (Source: The Copenhagen Diagnosis, 2009)

[3] **The Copenhagen Diagnosis**, 2009: Updating the World on the Latest Climate Science. I. Allison, N.L. Bindoff, R.A. Bindschadler, P.M. Cox, N. de Noblet, M.H. England, J.E. Francis, N. Gruber, A.M. Haywood, D.J. Karoly, G. Kaser, C. Le Quéré, T.M. Lenton, M.E. Mann, B.I. McNeil, A.J. Pitman, S. Rahmstorf, E. Rignot, H.J. Schellnhuber, S.H. Schneider, S.C. Sherwood, R.C.J. Somerville, K. Steffen, E.J. Steig, M. Visbeck, A.J. Weaver. University of New South Wales Climate Change Research Centre (CCRC), Sydney, Australia, 60pp.

Radiative Forcing

The concept that is key to understanding most of the science discussions around climate change is Radiative Forcing (RF). Radiative Forcing measures the change in energy balance in the atmosphere: a positive measure indicates warming and a negative measure indicates cooling. Many factors contribute to RF including

- well-mixed greenhouse gases, e.g. carbon dioxide (CO_2) and methane (CH_4);
- short-lived gases and aerosols, e.g. carbon monoxide (CO) and volcanic dust;
- reflectivity changes due to land use;
- and solar irradiance.

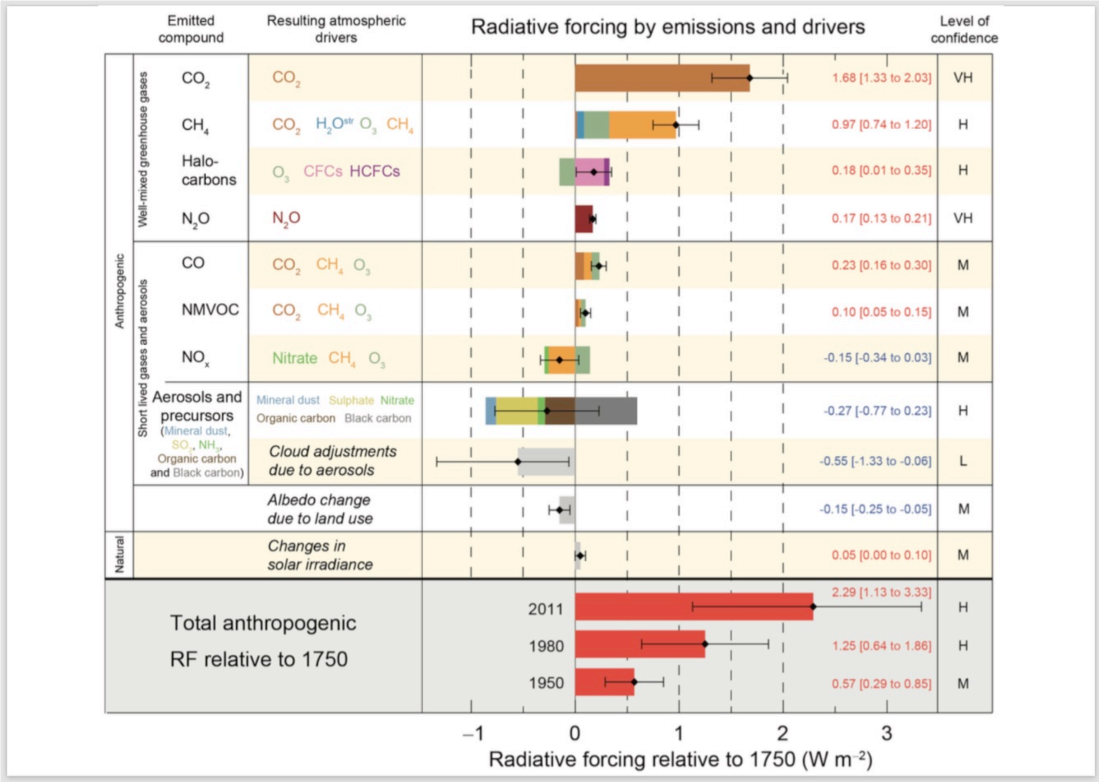
The first three are anthropogenic (caused by human activity), and the last is natural.

Figure 4, on the next page, is a summary of results for these different contributions to RF. It is taken from the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC), published in 2014.[4] A few points to help read the chart:

- This chart shows the Emitted RF (ERF) for the atmospheric greenhouse gases (GHG). Rather than trying to measure the current levels of gases in the atmosphere, ERF computes the amount of GHG released into the atmosphere, and the subsequent chemicals created by them.
- The righthand column shows, for each measurement, the confidence level of the authors of the AR5: VH - very high, H - high, M - medium, L - low.
- The largest uncertainties surround aerosols. These dusty compounds are not only reflective themselves, reducing the amount of solar radiation impacting the earth, but they also help to seed clouds and increase the cloud cover on the earth, which also reflects solar radiation.
- The earth's 'albedo' refers to the reflectivity of the surface of the earth.
- The error bars on the IPCC number for solar irradiance are small, but there is still some debate about both the magnitude and direction of that effect, largely because of differences in satellite measurements. See Appendix A for an excursus on Total Solar Irradiance (TSI).
- The bottom row of the chart shows the increase in the anthropogenic RF since 1750, having quadrupled since 1950.

[4] IPCC, 2013: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp. The specific graphic is found in the Summary for Policy Makers (SPM), p12.

Figure 4



The results represented in this chart are not particularly in dispute beyond the uncertainties given in the chart itself.[5] Also, the major contributors to RF enjoy either High or Very High confidence levels from the authors of the IPCC report.[6] Human beings are depositing Carbon into the earth's atmosphere and that will have an effect on the energy balance of the cryosphere, biosphere and hydrosphere of the earth. The idea that there has been an increase in surface temperature of the earth also seems to enjoy virtually universal consensus. One of the good questions that is often asked from outside the scientific community is whether or not there is solid evidence to believe the temperature rise is being caused by the Carbon in the atmosphere. It turns out the answer is, "yes, we do have solid evidence", so let's turn to that now.

5 There are intelligent, dissenting voices about the modelling as to how the concentration of Carbon in the atmosphere translates into a value for RF. While they raise helpful questions, to date, the alternative models put forward have already been considered, researched over the past 60 years, and, what is of value, has been incorporated into the current models. See Appendix B for an excursus on the process of modelling complex systems.

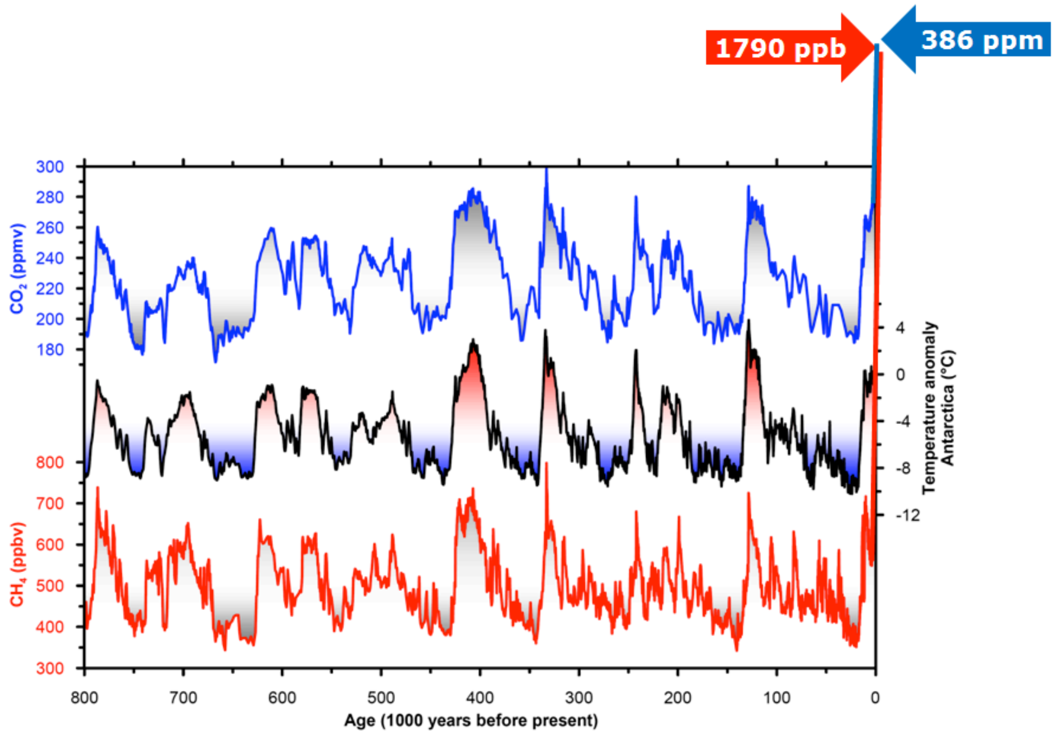
6 It is worth noting that the IPCC reports are meta-analyses of thousands of peer-reviewed studies from all over the world and a wide variety of academic disciplines. The IPCC does not do its own research, so its reports are trying to represent the current findings from independent researchers. Their sub-committees are pulling together results from thousands of journal articles to be able to provide these simple summaries for other researchers, governments, policy-makers, and the public. The methodology for creating the reports are outlined in detail on the IPCC website (http://www.ipcc.ch).

Anthropogenic Global Warming

The link between surface temperature rise and atmospheric Carbon concentrations is demonstrated in Figure 5, which shows the historical variation in concentrations of Carbon Dioxide (the blue line) and Methane (the red line) compared with variations in surface temperature measurements from Antarctica (the black line).[7] The regular variation captured here is due to changes in the Earth's orbit around the Sun. The correlation is striking. Throughout the earth's history, temperature seems to have varied in lock step with atmospheric Carbon concentration and we have no evidence to suggest that this behaviour has changed or will change. This graph leaves us with the fairly obvious conclusion that human activity - which results in depositing carbon in the atmosphere - is affecting the temperature of the earth.

One last point to note from this graph is the current levels of Carbon in the atmosphere. They are shown in the blue and red arrows above the righthand edge. Carbon Dioxide is currently at 1.5 times the historical maximum and Methane at 2.5 times, and this has come about over the past 200 years. If Physics works the same for the next 100 years as it has for the past few thousand, we should be expecting a corresponding rise in temperature on the earth, and that rise will be well in excess of what the earth has experienced since the advent of humanity.

Figure 5



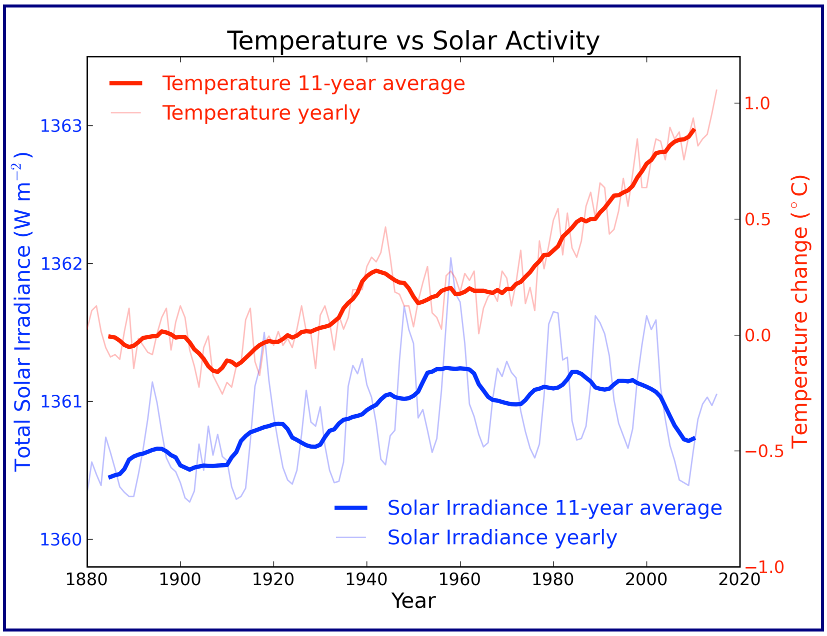
Precisely how much the temperature will rise and the impact it will have on life on earth is another question, and we will need to leave that to the experts in modelling that kind of thing. Another question to ask, however, is whether there are other factors that mean human activity, despite its definite impact, contributes such a small proportion that we can safely ignore it.

[7] This graphic was accessed at http://www.iceandclimate.nbi.ku.dk/research/past_atmos/composition_greenhouse/ on 11/10/2016.

The short answer is, “no”. There are currently no other contenders that dwarf human activity in that way and Figure 4 which shows the contributions to RF illustrates this. There is a suggestion that the sun may be behind the measured temperature rise despite its insignificant showing in Figure 4 and the reason for this suggestion can be seen in Figure 6 (below).

Figure 6 shows the Total Solar Irradiance (TSI), blue, against the temperature change, red.[8] The regular oscillation is the 11-year sunspot cycle, but the darker lines show the general trends. It is notable that from 1880 (our earliest records) to 1970, TSI tracks fairly well with temperature change. Of course, TSI and temperature diverge after 1980. What makes this somewhat more complicated is that the result we get post-1980 will depend on which set of satellite data we trust to give the most accurate numbers. It is likely that the best data is shown here, but there is other data that shows more of a levelling off of TSI, and also even data that shows a slight upturn since 1980 (see Appendix A for more information on TSI). Those data sets still don't show a strong correlation with temperature, but slightly stronger than what is pictured.

Figure 6



Another difficulty for the idea of TSI as the driver of global warming is that the 11-year solar cycle is not reflected in the temperature measurements. That is, the temperature, as ragged as the numbers are, does not follow the same 11-year oscillation as the TSI data. This suggests that the IPCC RF table in Figure 4 is indeed accurate in showing that TSI does have an impact on global temperatures, but it is at the 0.3% level.

Given the divergence of the TSI data from the change in temperature, we are left for now with no explanation for the temperature rise other than increasing atmospheric Carbon concentrations from human activity.

[8] The graphic was produced for skepticalscience.com (http://www.skepticalscience.com/solar-activity-sunspots-global-warming.htm), but the data is from Krivova, N. A., S. K. Solanki, T. Wenzler, and B. Podlipnik (2009), Reconstruction of solar UV irradiance since 1974, J. Geophys. Res., 114, D00I04, doi:10.1029/2009JD012375.

Concluding remarks

Our first response when dealing with issues of this complexity and specialisation should be humility. The expertise involved in achieving these results is mind-boggling: experimental design; data collection that involves instruments located from space right down to the bottom of the ocean; mathematics that uses the entire English and Greek alphabets; whole careers spent trying to get a satellite launched to make a single, key measurement; constant questioning by academic peers; drawing links with all other known research into similar areas; and supercomputer number crunching to rival ASIO.

Few, perhaps none, of us working outside the relevant scientific disciplines have the training or experience to confidently spot flaws in the IPCC research report, or to formulate a genuinely new challenge to the Science underpinning climate predictions today. We should, however, all be able to seek answers, in humility, from those whose skills outstrip our own.

Secondly, we need to understand why people seem to be so divided on this issue and so passionate on both sides. It's not because the integrity of the scientific enterprise is hanging in the balance, nor because the research and results are that exciting. It's because the results are being used to call us to action. Science is good at predicting the consequences of actions. Science, as an enterprise, doesn't care which actions we choose. It is not invested in its predictions. It merely lays out the options, so that human beings, as moral agents, have as much information at their fingertips as possible when they have to choose what action to take.

People are passionate about climate science because its findings have implications for moral agents and sometimes those moral agents don't like the implications. People don't tend to engage in social media campaigns against Physics departments because of an objection General Relativity, nor do they make a habit of picketing English Literature departments because they don't like someone's interpretation of Shakespeare. Why not? Because General Relativity and Shakespeare do not make impositions upon us. If we choose to invest our energy in global conspiracy theories about the corruption of science perhaps we should ask ourselves the difficult question: why do we prefer that course of action over the thoughtful reflection on the predictions of science and how we can best act to honour God and love our neighbour?

Thirdly, Science gets things wrong, sometimes in the big picture, sometimes in the details, sometimes for centuries, sometimes for a few days. The fact that Science can today make a claim that becomes a point of ridicule tomorrow is exactly the way Science is supposed to work because it means we are learning. Every day, on average, Science is "less wrong" and that is exciting and laudable. We can enjoy Science for the good gift it is, a tool for our rule over creation in the image of God.

Appendix A

Total Solar Irradiance

The total energy impacting the earth from the Sun, or the Total Solar Irradiance (TSI), oscillates on an 11-year cycle, but also shows long-term average trends both up and down throughout history. Because of the obvious common sense possibility that these trends in TSI are behind the current measured warming of the earth, lots of work has been done to understand the variations in TSI over time as well as its significance as a factor for global warming.

In the main text, we have indicated why it is virtually impossible that variations in TSI can explain global warming, i.e. trends in TSI do not correlate with changes in surface temperature, temperature changes do not mirror the 11-year cycle in TSI, and variations in TSI account for only 0.3% of the total computed radiative forcing. In light of that, this appendix is not an argument for or against TSI as a driver of global warming, but rather a picture of the kind of work that goes into any numbers or statistics that appear in an IPCC report and the peer-reviewed research studies that lie behind them.

Below (page 14) is an excerpt from the AR5 on how they decided which measurements of Total Solar Irradiance should be used for the report. This section is but 3 pages from a 1535 page document explaining the various effects that need to be taken into consideration when trying to summarise thousands of studies on issues related to climate change. The graph shows the different data sets that are being discussed.[9]

The report is written somewhat in science-speak and, even then, the different data sets will only be recognisable to solar astronomers who themselves study TSI. Here is an idea, in slightly more plain language, of the issues considered when trying to determine which TSI data to use for the report:

- The difference between TIM and other data sets.
  - TIM is likely the more accurate absolute value of TSI
  - The difference in absolute values is about 0.3% which is within the errors in the measurements
  - TIM is more recent and so cannot show the long term trends in TSI
  - Conclusion: use a different data set to understand the trends in TSI
- The difference between the three, longer-term composite data sets based on satellite data
  - ACRIM, RMIB, and PMOD
  - They each use some of the same data sets in their composites
  - ACRIM and PMOD both use Hickey-Frieden (HF) Radiometer data before 1981
    - The HF instrument suffered degradation before 1981
    - HF data was subsequently corrected
    - ACRIM ignored the correction in its composite, while PMOD took the correction into account

[9] IPCC, 2013: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, p689.

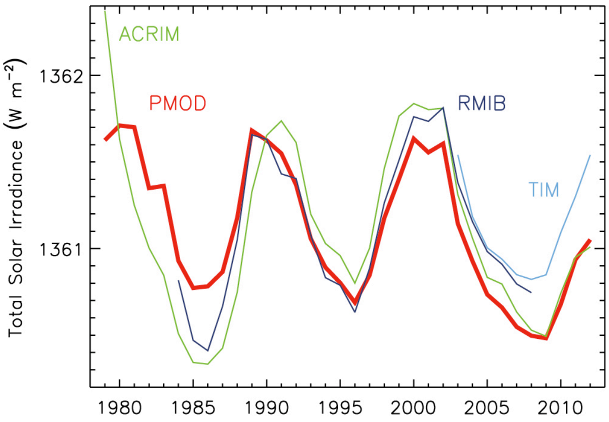
- How to bridge a gap in the ACRIM composite from 1989 to 1991
  - Again, the HF data shifted during that time creating an offset between 1989 and 1991
  - Again, ACRIM ignores the shift in HF data and the difference in minima between 1985 and 1996 in ACRIM, which is significantly larger than in PMOD
  - RMIB also ignored the shift in HF data and shows a similar trend to ACRIM
  - The differences create trends in the longer-term TSI that may be instrumental artefacts rather than physical reality
- How to assess the trends in the data
  - ACRIM rises through 1996 and then declines
  - RMIB continues to rise through 2008
  - PMOD declines from 1986
    - Unlike ACRIM and RMIB, the decline in PMOD correlates with sunspot numbers, which is what would normally be expected
  - ACRIM TSI correlates with the variation in cosmic ray numbers impacting the atmosphere
    - If those two phenomena are truly correlated than ACRIM would indicate that TSI has been on a long-term decline throughout the 20th century
    - Other long-term reconstructions of TSI predict the opposite
  - Projecting the ACRIM trend back to the Maunder Minimum, a sunspot minimum between 1645 and 1715, predicts a brighter sun at that time than now
    - Other long-term projections predict the opposite
- Studies now confirm the need to correct HF data
  - The instrument degradation has now been studied and the effect on the data understood
  - The HF radiometer had issues maintaining its physical pointing in the sky, which also affected the measurements
  - Independent measurements of TSI from solar magnetograms show that HF data needed recalibration

Those are the reasons why the PMOD TSI composite has been selected for inclusion in the AR5.

Each one of those points represents anywhere from 5-50 peer-reviewed research studies that feed into the discoveries and analysis required to reach consensus on how to proceed at each step above. These documents are freely available at http://www.ipcc.ch, where you can also find lists of which scientists are on which subcommittees as well as the methodologies they employed in making decisions about what went into the report. There are also fact sheets and summaries for policymakers (SPM) that are far more accessible than what is quoted above. Each claim is labelled with a confidence level from the sub-committee that produced it, to help readers get a feel for what we can be quite sure of and what is still more of an open question.

8.4.1.1 Satellite Measurements of Total Solar Irradiance

Total solar irradiance (TSI) measured by the Total Irradiance Monitor (TIM) on the spaceborne Solar Radiation and Climate Experiment (SORCE) is 1360.8 ± 0.5 W m^{-2} during 2008 (Kopp and Lean, 2011) which is ~4.5 W m^{-2} lower than the Physikalisch-Meteorologisches Observatorium Davos (PMOD) TSI composite during 2008 (Frohlich, 2009).The difference is probably due to instrumental biases in measurements prior to TIM. Measurements with the PREcision MOnitor Sensor (PREMOS) instrument support the TIM absolute values (Kopp and Lean, 2011). The TIM calibration is also better linked to national standards which provides further support that it is the most accurate (see Supplementary Material Section 8.SM.6). Given the lower TIM TSI values relative to currently used standards, most general circulation models are calibrated to incorrectly high values. However, the few tenths of a percent bias in the absolute TSI value has minimal consequences for climate simulations because the larger uncertainties in cloud properties have a greater effect on the radiative balance. As the maximum-to-minimum TSI relative change is well-constrained from observations, and historical variations are calculated as changes relative to modern values, a revision of the absolute value of TSI affects RF by the same fraction as it affects TSI. The downward revision of TIM TSI with respect to PMOD, being 0.3%, thus has a negligible impact on RF, which is given with a relative uncertainty of several tenths of a percent.



Since 1978, several independent space-based instruments have directly measured the TSI. Three main composite series were constructed, referred to as the Active Cavity Radiometer Irradiance Monitor (ACRIM) (Willson and Mordvinov, 2003), the Royal Meteorological Institute of Belgium (RMIB) (Dewitte et al., 2004) and the PMOD (Frohlich, 2006) series. There are two major differences between ACRIM and PMOD. The first is the rapid drift in calibration between PMOD and ACRIM before 1981. This arises because both composites employ the Hickey–Frieden (HF) radiometer data for this interval, while a re-evaluation of the early HF degradation has been implemented by PMOD but not by ACRIM. The second one, involving also RMIB, is the bridging of the gap between the end of ACRIM I (mid-1989) and the beginning of ACRIM II (late 1991) observations, as it is possible that a change in HF data occurred during this gap. This possibility is neglected in ACRIM and thus its TSI increases by more than 0.5 W m^{-2} during solar cycle (SC) 22. These differences lead to different long-term TSI trends in the three composites (see Figure 8.10): ACRIM rises until 1996 and subsequently declines, RMIB has an upward trend through 2008 and PMOD shows a decline since 1986 which unlike the other two composites, follows the solar-cycle-averaged sunspot number (Lockwood, 2010). Moreover, the ACRIM trend implies that the TSI on time scales longer than the SC is positively correlated with the cosmic ray variation indicating a decline in TSI throughout most of the 20th century (the opposite to most TSI reconstructions produced to date; see Section 8.4.1.2). Furthermore, extrapolating the ACRIM TSI long-term drift would imply a brighter Sun in the Maunder minimum (MM) than now, again opposite to most TSI reconstructions (Lockwood and Frohlich, 2008). Finally, analysis of instrument degradation and pointing issues (Lee et al., 1995) and independent modeling based on solar magnetograms (Wenzler et al., 2009; Ball et al., 2012), confirm the need for correction of HF data, and we conclude that PMOD is more accurate than the other composites.

Appendix B

Modelling physical systems

Real physical systems are impossibly complex. That is, it is genuinely impossible to accurately represent real physical systems with the brains we've been given and the computer technology we currently enjoy. Everything in the world is connected to everything else and has some sort of impact on any given part of the system. If you don't believe in Astrology, you should. Well, not in the sense that popular magazines would have you believe your future can be determined according to the stars, but in the sense of the basic principle - *stuff is connected*. We really *do* feel a gravitational pull from Jupiter and a particular arrangement of lights in the sky at night *will* produce one set of neural pathways in our brain rather than another.

All physical models are simplifications of the real system and, therefore, are 'missing' something. When we learn physics in high school, we are taught to ignore friction as we calculate the velocity of a block sliding down an inclined plane. When computing the tension on a weight hanging from a pulley, we ignore the moment of inertia of the pulley. These are relatively simple 'missing' components that we can add back into the model as we grow in our knowledge of mathematics and physics, and they are significant components that will affect our experience of the physical system in question. That is, my prediction of the velocity of the block will be noticeably wrong without friction taken into account, and if I want to know when to put out my hand to catch the block as it slides off the end of the plane, I will miss it. On the other hand, I also haven't included the gravitational pull of Jupiter in the calculation. As it turns out, if I calculate that effect, I will discover that the effect is so small, it won't affect the practical working of the system. I won't miss the block. Sometimes we can simply, and entirely reasonably, ignore certain factors in our models, when we can satisfy ourselves that the effect is negligible for what we are trying to achieve.

There is another method for simplifying models that involves looking for proxy parameters that can represent the behaviour of a system that is otherwise extremely complex in the details. That is, scientists will take the time to make complicated, expensive, and time-consuming measurements of many different physical quantities in a system over a period of time, in order to discover the relationships between different pieces of a system. In analysing the results, they may find that one of the simpler measurements they made, e.g. sticking a thermometer in the ground, allows them, with their new understanding of the system, to predict the values of the other measurements to within the accuracy required. This is a happy result because they can now model a whole system based on that one parameter and they can make that simple, low-cost measurement over and over again and in many different locations. This is an improvement over the alternative in which scientists have to measure every aspect of the system every time they want to make a prediction, and in which the reach of their models is limited to short time scales or very localised regions.

Often climate models work this way. For example, surface temperature is one of those proxy parameters that give an acceptably accurate understanding of the wider system, such that if the models predict the right surface temperature, we can be confident that the various approximations we've made within the models are sound.

There are many intelligent people in our world, praise God, and it is straightforward for them to look at a climate model and see that there are hundreds of assumptions being made to simplify the model. With only a little bit of scientific knowledge, it is also straightforward to show that the pieces of the physical system that are ignored in the model should be significant for understanding the system accurately. For example, the different greenhouse gases in the atmosphere vary in their effectiveness by temperature and density, and, therefore, altitude. As one gas is heated by the sun, it will change in its properties and altitude, which will in turn affect gases on other layers, and so on.

Demonstrating that the interconnectedness of the greenhouse properties of gases will affect the models is not all that difficult. This has led many to conclude that the models are inaccurate, and perhaps you can see why.

What is far more difficult, however, is to read back through the past 60 years of research to understand the pedigree of the current model, including all of its assumptions, and discover how those assumptions entered into the models, how they were justified, and what level of precision is being sacrificed by simplifying the system in those particular ways. In the vast majority of cases, that research has been done, the models are well grounded in actual measurements that have yielded useful proxy parameters, and they can be demonstrated to be accurate to the level they claim.

The main point here is that while there are intelligent people with sensible questions about assumptions and inaccuracies in models, the scientific community is highly likely to have already asked those questions, researched responses to them, and incorporated the answers into the latest round of models. No human system is perfect, but peer-review, which was set up by Christians because they believed in sin, does an extremely good job of keeping scientists focused on finding the truth rather than producing any old result for the sake of the next round of research funding.

Be encouraged. Science works pretty well. If you think you have spotted a problem with a model or an experiment, ask the people involved. Scientists enjoy talking about their work and, if you ask them to help you understand something, they will. They are used to hard questions, much harder, in fact, than people outside their own field usually ask, so the odds are they can point you to helpful explanations.

Further Reading

IPCC, 2013: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.

In response to the report of the Committee on Gospel, Society and Culture, brought to the General Assembly of the Presbyterian Church of Australia in NSW in July 2017, the Assembly resolved to circulate the report more widely as discussion document for use by individuals and congregations.

For more information about The Gospel, Society and Culture committee see www.gsandc.org.au .

The research and writing for this report was conducted by G,S&C committee member, Dr Lewis Jones. Dr Jones earned his PhD in Astrophysics from the University of North Carolina before moving to Australia for his first postdoctoral research position at the University of New South Wales. He has since completed a BD from Moore Theological College and works for AFES leading The Simeon Network, a network of Christians working in academia.

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