

## COMMENTARY

### Professor Bauer Has It Backwards

PETER A. BANCEL

Institut Métapsychique International, Paris, France

In his Essay Review “Climate Change Science or Climate Change Propaganda?” in this issue, Henry Bauer informs us that there is no valid scientific support for anthropogenic global warming (AGW), that predictions of future warming are erroneous, and that a propaganda campaign is being perpetrated by mainstream science to cover up these embarrassing errors. Worse, the campaign is succeeding as pundits and the media buy into the received dogma and the consequences appear dire. The world risks widespread and unnecessary economic disruption by responding to an illusory problem, and “highly informed experts” who challenge the climate change consensus are being hurtfully sneered at as they are dismissed out of hand.

The last point may be familiar to Professor Bauer, who is no stranger to readers of this Journal’s pages. He has long held a contrarian position on the causes of AIDS, and I imagine that the rejection of his views can sting. Still, it’s not clear what exactly has motivated Professor Bauer’s wide-ranging Essay Review, unless it’s just the lure of crusading against the imposed groupthink of mainstream science. That is fine and may well offer some good sparring as long as one prepares one’s case well. Unfortunately, Professor Bauer has not done so, and his arguments against AGW don’t stand up when confronted with the data and research.

To make his case, Exhibit A is the booklet *Climate Change: Evidence and Causes* published by the London Royal Society in collaboration with the U.S. National Academy of Sciences, which he dissects for us in his Essay Review. In a nutshell, he argues that since the science is patently wrong, disseminating a pamphlet affirming it amounts to proof of collaborative propagandizing. Along the way, we learn that comparisons with previous documents, duplicitous choices of wording, and even the use of British spelling provide supporting evidence of the collusion. However, it’s not necessary to debate these points. To undo Professor Bauer’s argument, it suffices to expose the errors in his claim that the science is wrong. The rest of his propaganda argument falls after that.

As the Essay does not describe the basics of climate science, it’s perhaps

helpful to give a brief sketch. Historically, the physics of the greenhouse effect was established and demonstrated in the 1800s. Greenhouse gases warm the Earth by blocking outgoing longwave radiation (heat), thus altering the energy balance between the Sun's warming and the Earth's natural radiative cooling. The first AGW predictions were made at the turn of the twentieth century based on estimates of CO<sub>2</sub> production from industrial sources. For a few decades it seemed that the oceans might safely absorb the excess gas until new calculations showed otherwise. That prompted the first systematic, ongoing measurements of atmospheric CO<sub>2</sub> by Charles Keeling beginning in 1958, and continued monitoring confirms the predicted, inexorable rise. The CO<sub>2</sub> greenhouse effect is thus straightforward physics, and this has been known about for almost two centuries. Today, humans add CO<sub>2</sub> to the atmosphere at 100 times the natural rate, and significantly faster than during the massive volcanic eruptions that led to severe climatic change and mass extinctions seen at several periods in the geologic record.

In the simplest terms, climate is determined by the concentrations of greenhouse gases (GHGs) in the atmosphere and by how sunlight hits and reflects from the Earth. Climate evolves when these change. The primary solar factors are the natural variations in the Earth's orbit and axis that cause the so-called Milankovitch cycles (with periods from 20,000 to 110,000 years) and drive the Ice Ages.<sup>1</sup> Although water vapor contributes a greenhouse effect two to three times larger, CO<sub>2</sub> is the main "control knob" of climatic change because its atmospheric lifetime is long and its presence is necessary to maintain the positive water vapor feedback. CO<sub>2</sub> has fast sources in volcanic eruptions and slow sinks in the weathering of silicate rock. Because the weathering is dependent on temperature, the long-term CO<sub>2</sub> cycle acts like a thermostat: When CO<sub>2</sub> concentrations go up the temperature rises, increasing the rate of chemical weathering which in turn brings CO<sub>2</sub> levels, and temperature, back down. Because this process is slow (it takes about a million years), it is possible for the sources to drive CO<sub>2</sub> levels far from equilibrium and cause excess warming for long periods. This is the basic concern underlying AGW: While some GHGs are relatively short-lived, the long atmospheric lifetime of CO<sub>2</sub> means we can set in motion climatic changes that will continue for many generations. Despite the added complexity of feedbacks and other factors, advances in paleoclimatology during the last 30 years make clear CO<sub>2</sub>'s central role in the Earth's climate. (By the way, Richard Alley's excellent lectures on the subject are available on the Internet and are great fun to watch.)

Understanding things on shorter timescales requires finer data and modeling of the physics, chemistry, and biology that affect GHGs,<sup>2</sup> changes

in the Earth's albedo (the average surface reflectivity, which depends on ice, snow, cloud, and vegetation coverage), and alterations of heat transport mechanisms associated with ocean currents. The dynamics on the timescale of a century, relevant for our current situation, is where computer models come into play. Climate models are important in part because they provide projections of future climatic changes for policymakers and industry leaders. Demonstrating the models' reliability is thus essential if they are to inform policy debates, and this is done by determining how well model simulations of the past agree with historical records and temperature reconstructions from geological and other Earth science datasets. Professor Bauer's main contention is that the models fail to reproduce the temperature records of the last century, which leads him to conclude that pamphlets affirming future climate change are unscientific propaganda.

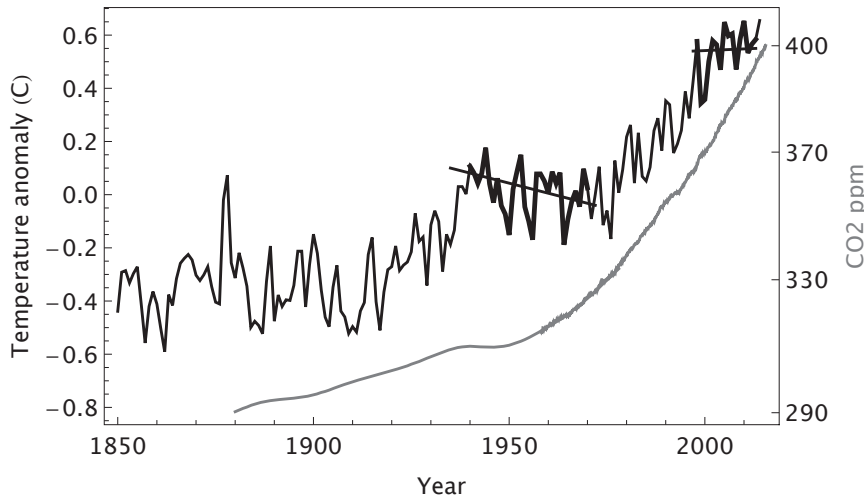
The contention that the models fail is simply wrong. The models not only reproduce recent global temperatures well, down to the scale of a few decades, but more importantly they show that without the presence of extra CO<sub>2</sub> from the burning of fossil fuels, the temperature rise of the last century cannot be explained. Professor Bauer errs because he draws much of his information from dubious sources found on the Internet (as we see from his Notes and References Cited) rather than from the published research. He also confuses how models differentiate between long-term warming trends and natural short-term variability. To understand this, we can indicate where the research contradicts his conclusions. Professor Bauer begins by claiming that the models are based on unfounded assumptions (p. 626):

the mainstream position rests chiefly on two unproven points:

1) . . . any heat absorbed in the atmosphere by CO<sub>2</sub> must go into heating the atmosphere, earth, and oceans. Further, computer models . . . assume that a feedback mechanism amplifies the heat absorbed by atmospheric CO<sub>2</sub> (Singer 2014).

2) Misconstruing as evidence of causation the gross overall correlation from about 1850 to the present between CO<sub>2</sub> levels and global temperature. But correlation never proves causation.

He goes on to argue that the climate is too complex to model, the proof being that models fail to reproduce two periods of the global temperature record: the slight cooling period of 1940–1970 and a “warming slowdown” over the period 1998–2012 (see Figure 1). Claiming, incorrectly, that the models fail, he concludes:



**Figure 1. The Berkeley reconstruction (<http://berkeleyearth.org>) of global surface temperatures showing a rise of about 1 °C over the last century.** The periods in question are indicated by bold traces and trend lines. The smooth curve shows atmospheric measurements of CO<sub>2</sub> concentration in parts per million (ppm) from 1958 to the present, and a reconstruction from ice cores for earlier years. While the temperature rise is seen to track CO<sub>2</sub> over the long term, the relationship is not expected to be linear. Variability in both natural and anthropogenic forcings results in decadal variations of global surface temperatures that are accurately captured by climate models. Fluctuations in the temperature record arise from both climate variability and measurement uncertainty. The latter has improved over time, which explains the decrease in the year-to-year fluctuations in the last 50 years or so.

No model accounts for that, showing that natural influences missing from the models can outweigh any greenhouse warming by CO<sub>2</sub>. It follows that no projections from these models into the future should be taken seriously.

To take his points in order, the CO<sub>2</sub> greenhouse effect is a simple, well-established fact of physics. Similarly for the amplifying effect of atmospheric water vapor (referred to in point 1), which increases with temperature and provides a positive feedback to CO<sub>2</sub> warming. These are anything but “unproven,” and denying them implies we must jettison physics, a move that Professor Bauer might resist upon reflection.

The correlation-is-not-causation argument reveals that Professor Bauer does not contest the last century’s overall increase in global temperature, but it makes for a disingenuous gambit. A main occupation of science is precisely the determination of causes of correlations, and he implies that this has been

collectively forgotten by climate scientists. It is obvious that determining causes requires additional evidence from measurement and experiment. The International Panel on Climate Change (IPCC)<sup>3</sup> uses the term “attribution” to indicate causal determination, and it devotes considerable attention to attribution methodology (Hegerl 2007). The converging lines of evidence for a causal relation between warming and GHG concentrations are clear. Spectroscopic measurements of atmospheric radiation at the Earth’s surface show an increase at precisely the wavelengths corresponding to GHG emission lines, and the spectral intensities track with GHG concentrations (Feldman et al. 2015). Satellite measurements of outgoing radiation find a corresponding deficit at these wavelengths. A key observation is that, as predicted by greenhouse warming, the lower atmosphere is warming faster than the stratosphere (the opposite would occur if warming were due to increased solar activity). These and other measures leave no doubt that the warming is due to increasing GHG concentrations.

The attribution of global warming to anthropogenic causes can also be demonstrated by varying climate-sensitive parameters of the Earth system. Although experimentation on this scale isn’t possible (aside from the one experiment we are currently running by burning fossil fuels), computer models can serve as surrogates for the global climate system. Climate science makes extensive use of modeling to make causal determinations and draw other useful inferences about the Earth’s climate. Professor Bauer’s main objection focuses on model uncertainties, and further on in his Essay (p. 633) he summarizes:

... the prediction of long-term change resulting *primarily* from steadily increasing atmospheric CO<sub>2</sub> comes from computer models that account for neither the “slowdown” of the last decade-and-a-half nor the cooling from about 1940 into the 1970s that had then caused climate scientists to warn about an impending Ice Age. These failures demonstrate unequivocally that the computer models are flawed; since they are wrong even in the short term and for the recent past, they certainly cannot be given credence for the longer term.

Not only is the argument’s premise incorrect, but to reason that the accurate prediction of short-term variability is required for reliably establishing long-term trends misconstrues how models are used. It confuses the detailed dynamics of the climate system, which is complex and requires fine-grained data to model, with the drivers of overall change, for which the variability averages out. Following his reasoning, we should not trust regional weather forecasts—notably accurate these days—because they cannot predict when a thunderstorm will occur in my neighborhood.

The extent of long-term warming predicted by the models of 20 years ago agrees remarkably well with the far more sophisticated models of today. This is precisely because the overall warming trend is a consequence of known physics and chemistry, and these are adequately represented by earlier models. The reason climate science continues to refine its models is not from a need to establish further evidence for AGW (even without models, theory and measurement alone make the case), but rather to provide guidance for solutions to the problem. This includes insight into how climate change may impact different regions of the globe and understanding how climate sensitivity depends on factors we can measure and perhaps control.

Far from calling the reliability of models into question, the two cited periods provide case studies that demonstrate the models' utility. These periods have been studied extensively and the factors responsible for the short-term variability identified. When the data are input to models, there is good agreement between them.

The period of slight cooling from 1940 to 1970 was largely due to an increase in sulphate aerosols from industrial pollution during World War II and the ensuing post-war economic expansion. Aerosols contribute to the Earth's albedo by reflecting sunlight, and the magnitude of this negative forcing accounts for most of the temperature decline. Among the supporting evidence for aerosol cooling are decadal records that show cooling for daytime measurements only, with rising temperatures for nighttime data. This is to be expected if greenhouse warming is concurrent with aerosol cooling (which happens only during daylight hours). The aerosol albedo overwhelmed greenhouse warming, but both effects were active, and this can be seen in the data. Overall warming resumed as CO<sub>2</sub> levels continued to rise and as the aerosol concentrations declined with the passage of the U.S. Clean Air Act of 1970 and similar laws in other developed countries. Models that input the historical aerosol levels yield temperatures consistent with the historical record for the period.

In passing, Professor Bauer references an article in the U.S. news publication *Time* to suggest that climate scientists mistakenly interpreted the cooling as the start of a new Ice Age. There was speculation about whether the cooling could persist, but it was a minority view and the prospect of AGW dominated the discussion even then. From 1965 to 1979 only 7 of 68 papers addressing the topic advanced an Ice Age explanation, while 42 proposed AGW as the most important force shaping the planet's climate on human timescales (Peterson, Connelley, & Fleck 2008). The Ice Age proposal was dropped as data and modeling made clear the interplay between AGW and aerosol cooling. The episode is historically noteworthy since it marks the transition of a fledgling field into a mature interdisciplinary

science as geologists interested in Ice Age dynamics and atmospheric chemists working to measure and model changes in CO<sub>2</sub> concentrations came together to understand the brief period of cooling.

The more recent and much weaker “warming slowdown” has received considerable attention. In the big picture, it is not particularly important since the main concern is how climate will change in the longer term, and not the occurrence of expected short-term variability. The oft-repeated claim that “the warming has stopped” is a misreading of the data that is understood correctly once natural and anthropogenic factors of climate variability are input to the models. These include aerosols from a documented increase in volcanic activity in the 2000s and the occurrence of several strong cooling episodes of the El Niño Southern Oscillation in the Pacific (the ENSO circulation transfers heat between the atmosphere and the subsurface ocean; it is one of the most important drivers of short-term climate variability). The negative ENSO ended in 2013. Not incidentally, 2014 was the hottest year in the global temperature record and 2015 is on track to beat that record.

The 1998–2012 fluctuation has been studied intensely, for two reasons. First, the most recent IPCC assessment<sup>4</sup> highlights that the period’s duration of 15 years corresponds roughly to the prediction horizon of current climate models—the timescale over which uncertainties in the modeled short-term variability grows large. Earth data from the period is the most detailed on record, particularly for ocean currents and temperatures,<sup>5</sup> and this provides an opportunity to sort out different contributions to the variability. Several journals have recently devoted special attention to research on the “slowdown” fluctuation and the lessons it implies for models.<sup>6</sup> Second, although the fluctuation has been widely misrepresented to claim that AGW has “stopped,” it is an instance of the climate variability that is expected to occur even as warming continues, just as was seen for the 1940–1970 period. The distinction between natural variability and model uncertainty is not easy to convey to the public, and new research has addressed this issue as well (Lewandowsky, Risbey, & Oreskes 2015).

By varying parameters during simulations, models can reveal how different factors affect climate change. This flexibility has also been used to test model reliability. Two examples are worth noting. One is that if the human contribution to atmospheric CO<sub>2</sub> is removed during simulations, models do not reproduce the observed temperature rise, even when other parameters are allowed to range freely<sup>7</sup> (Meehl et al. 2004). When the extra CO<sub>2</sub> is included, models track the direction and magnitude of the temperature trend. Second, as reviewed above, short-term temperature trends can be reproduced when models are initiated with real world data. A recent study (Risbey et al. 2014) turns this around to show that when models that allow

for random ENSO variability are run, the simulations that most closely match the observed temperature trends are those that, by chance, selected the actual El Niño record. This further indicates that models reliably track the relation between ENSO and global temperature variability.

Professor Bauer is right to think that variability in ocean currents, volcanic activity, and the like contributes to model uncertainty. This is why many simulations are averaged when estimating the longer trend of AGW. But it is incorrect to state that projections of long-term trends are unreliable, or that models cannot estimate variations in the historic temperature record when initialized with real world data within the prediction horizon.

Professor Bauer's indictment of climate models shows that he largely ignores the extensive research of the past decades, and it is interesting to see where he gets his information. A number of the sources are from people who are not climate scientists and from websites that engage in ideological advocacy. We can look at a few. Fred Singer is a physicist respected for his contributions to the earth and space sciences. However, he has spent much of his career in campaigns to refute the scientific basis of policy responses to the ozone hole, acid rain, and the dangers of second-hand smoke. Not only was the science proven correct in each case, but the cooperation between scientists, government, and industry greatly mitigated adverse impacts and demonstrated that viable solutions to complex problems are possible when institutions work together. On a personal note, I was employed at IBM research in the late 1980s and was impressed by what I saw of IBM's involvement in the effort to reduce CFC emissions and mitigate ozone depletion. Management was not thrilled by the cost and effort it demanded, but as the science was clear, adequate solutions were sought, industry standards were implemented, and things moved on. To my mind, the characteristic objections of capable scientists like Singer and Professor Bauer have more to do with a lack of trust in cooperation and governance, than in the science itself. A profile of Dr. Singer that elaborates on this point is found in the book *Merchants of Doubt* (Oreskes & Conway 2010), which sheds light on the murkier side of the climate debates.

Among the texts cited in Bauer's Essay Review is a self-published handbook by meteorologist David Dilley. Dilley argues that climate scientists are in it for the grant money and that, anyway, climate always changes:

In the Old Testament of the Bible, Genesis I (Verses 9–19) says the cycles of earth's days, seasons, oceans, and atmosphere were created by God the creator of earth and the universe. Does this mean humans have created global warming? Of course not, these are God's natural cycles.



This does not give us much confidence in Professor Bauer's selection of sources, but it does suggest how errors make their way into his Essay Review. The remainder of his text veers between unsubstantiated critiques of the science and supposed evidence of incompetence and propaganda. There is too much to rebut and this is not a surprise. A common rhetorical technique (colloquially known as a Gish gallop) is to overwhelm any rebuttal by presenting a raft of superficially plausible half-truths and strawman arguments that take unreasonable effort to unwind and refute. Indeed, it has taken several pages just to expose the claim that models fail, and we've only advanced a few paragraphs into the Essay Review. But since that is the core of the argument for "propaganda science," it is not necessary to go through it all. Many of Professor Bauer's arguments are standard fare, and there are resources that catalogue and carefully refute the most common myths. The resources also provide copious citations toward the primary literature.<sup>8</sup> Still, it is useful to drive home the point by going through several more of Professor Bauer's objections.

Next in the Essay Review is a claim that the recent warming cannot be "unprecedented" because past temperature records are not accurate or fine-grained enough to support such a claim. However, nowhere does the booklet under review assert that the warming is unprecedented (that qualification is attributed to recent CO<sub>2</sub> concentrations, not temperature). Even if one were to find such a statement somewhere else, and I imagine one could, it is beside the point. The worry about AGW is that the current increases of CO<sub>2</sub> and global temperature are fast by paleoclimatic measures, the rate of warming is increasing, and without action we risk significant levels of warming by the end of the century.

Professor Bauer complains about the use of statistical confidence intervals and their translation to terms such as "likely" or "highly likely." These are used to express degrees of uncertainty in data and analyses and he finds this unacceptably subjective. However, this is standard terminology for statistical uncertainties used across many disciplines and is explained in detail in the research literature, including the IPCC's reports.

Next is a meme found in the blogosphere that aims to cast doubt on climate scientists' integrity: In response to the alleged failure of models to account for the "hiatus" in warming since 2000, climate scientists have conspired to adopt the term "climate change" and drop "global warming" from their lexicon, thereby inoculating themselves against embarrassment due to the "pause" in warming.

Until a few years ago, "global warming" was the universally used shorthand for human-caused global warming. But since there has been no appreciable

warming globally for the last 15 years or so, the critics of carbon emissions have been using the term “climate change,” which cannot be contradicted or falsified.

The two terms mean different things, and both have been used in the scientific literature for more than 40 years. Global warming refers to a global rise in the Earth’s temperature due to increased GHGs, and climate change refers broadly to any alterations of the climate that result. Professor Bauer’s claim that substituting “climate change” for “global warming” is a recent “rhetorical sleight of words” is untrue. The IPCC was formed back in 1988 and I don’t need to remind the reader what CC stands for. A seminal 1956 paper on the topic was entitled “The Carbon Dioxide Theory of Climatic Change” (Plass 1956). In the research literature, “climate change” has always been the more frequent term, its use predating “global warming” by a decade or two.

The use of “global warming” in the press and media did spike sharply in 2007 shortly after the success of Al Gore’s documentary film *An Inconvenient Truth*, which employed the term extensively. After a few years, media usage of “global warming” declined and today both terms are used by the media with roughly equal frequency.<sup>9</sup> This is likely due to journalists gradually adopting climate scientists’ established language as well as an increased awareness that climate change more accurately describes the diverse impacts of warming such as species extinction and ocean acidification.

Professor Bauer makes much ado about extreme weather claims. It is not surprising that the news media may overstate a connection between weather events and climate, but he misrepresents what is said in the booklet, and by climate scientists in general. The chief concern raised by climate scientists is that warming increases evaporation, exacerbating droughts, while the excess water vapor in the atmosphere favors more intense storms. Other factors associated with warming can disrupt weather patterns and cause more severe coastal flooding, but caution is the byword in drawing conclusions about single events, and this is adequately expressed in the Royal Society’s booklet. Recently, a methodology for addressing the climate–weather relation has been developed (Trenberth, Fasullo, & Shepherd 2015), and research into the question is ongoing.<sup>10</sup>

Other objections concerning the Medieval Warm Period, the Little Ice Age, Arctic versus Antarctic sea ice loss, the role of the Sun, or why temperature initially precedes CO<sub>2</sub> rise when exiting the Ice Ages would take far too many pages to elucidate here. The curious reader is invited to refer to the cited resources,<sup>8</sup> where clear and concise rebuttals based on the science and the research can be found.

In conclusion, the claim that AGW skeptics have been treated unfairly by an organized propaganda campaign is a distortion that ignores the scientific research. In fact, Professor Bauer has it backwards: The organized distortion is quite the other way around.<sup>11</sup> Nor is it the case that the assessment of AGW is limited to “mainstream science.” Numerous independent institutions that have the resources and expertise to fully review the evidence concur that the international community needs to address the problem, despite the potential challenges the position implies for their various activities. They include<sup>12</sup> petroleum companies (Shell Royal Dutch, BP, Statoil, and ConocoPhillips, among others), the U.S. Department of Defense (especially the U.S. Navy), not to mention the Chinese government and many more.

### Notes

- <sup>1</sup> On very long time scales, a monotonic increase in the sun’s total energy output also needs to be taken into account. Total solar radiance increases by about 1% every 100 million years.
- <sup>2</sup> This includes a fast cycle of CO<sub>2</sub> exchange between the atmosphere, oceans, and the biosphere.
- <sup>3</sup> The International Panel on Climate Change is the United Nations body charged with synthesizing the evidence for climate change for the world’s governments in order to provide a common basis for policy deliberations.
- <sup>4</sup> AR5, Working group 1, chapter 9, box 9.2.  
<http://www.ipcc.ch/report/ar5/wg1/>
- <sup>5</sup> Monitoring of ocean temperature data was vastly improved in 2000 with the deployment of the Argo array of free-floating instruments. The 4,000 GPS-linked Argo floats relay in real time information on ocean currents, temperature, and salinity down to depths of 2,000 meters.  
<http://www.argo.ucsd.edu/>
- <sup>6</sup> See issues of *Nature Geoscience*, 7, (March 2014); *Nature Climate Change*, 4, (March 2014); *CLIVAR*, 15, (Summer 2015).
- <sup>7</sup> A helpful graphical depiction of the relative contributions of different climate forcings can be found at <http://bloom.bg/1GppERp> (on Bloomberg Business).
- <sup>8</sup> Two helpful resources that explain the science and provide rebuttals to standard counterarguments are <http://skepticalscience.com/argument.php> and <http://climate.nasa.gov/>
- <sup>9</sup> For media usage, the reader can make a comparative search of “global warming” and “climate change” on *GoogleTrends*.
- <sup>10</sup> A list of recent publications that treat the connection between weather and climate change can be found at <https://www.climatecommunication.org/new/features/extreme-weather/>

- <sup>11</sup> Funding by industry front groups that distort the science is well-documented. ExxonMobil and Koch Industries have been particularly active. <http://insideclimatenews.org/content/Exxon-The-Road-Not-Taken> (Brulle 2013). U.S. climate scientists have had their emails stolen, been faced with unfounded threats of legal action by U.S. Senators and District Attorneys, been subjected to abusive Freedom of Information requests and their personal information having been posted on advocacy websites, received threats to their persons and their families.
- <sup>12</sup> 81 major American companies have recently announced their support for a successful outcome to the Paris COP21 accords for international cooperation on climate change. <http://cop21.org/white-house-announces-commitments-from-81-us-businesses/>

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