Prof. Faustus contemplates benefits of a bargain with Mephistopheles. Humans made their own Faustian bargain via aerosol cooling to offset greenhouse gas warming. [Fig. 8 in Chap. 6. *The Faustian Bargain: Humanity's Own Trap*, in *Storms of My Grandchildren*, 2009.]

To Understand and Protect the Home Planet

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Global Warming in the Pipeline will be published in *Oxford Open Climate Change* of Oxford University Press next week. The paper describes an alternative perspective on global climate change – alternative to that of the Intergovernmental Panel on Climate Change (IPCC), which provides scientific advice on climate change to the United Nations.

Our paper may be read as being critical of IPCC. But we have no criticism of individual scientists, who include world-leading researchers volunteering their time to produce IPCC reports. Rather we are questioning whether the IPCC procedure and product yield the advice that the public, especially young people, need to understand and protect their home planet.

Discussion of our paper will likely focus on differences between our conclusions and those of IPCC. I hope, however, that it may lead to consideration of some basic underlying matters.

Three-pronged analysis. IPCC climate analysis leans heavily on GCMs (global climate models), too heavily in my opinion. We prefer a comparable weight on (1) information from Earth's paleoclimate history, (2) GCMs, and (3) observations of ongoing climate processes and climate change. This 3-pronged approach can result in rather complex papers, but, so, too, is the real-world complex. We use this 3-pronged approach in both the heavily peer-reviewed paper, "Ice Melt, Sea Level Rise, and Superstorms," published in 2016 and in our present "Global Warming in the Pipeline" (these papers hereinafter abbreviated as *Ice Melt* and *Pipeline,* respectively). Below I note specific travails and consequences for the *Ice Melt* paper that resulted from the fact that our 3-pronged approach differed from that of IPCC. I hope that some explanation here may help avoid a similar fate for *Pipeline*, as the world is running short on time to develop a strategy to preserve a propitious climate for today's young people and their children.

Guidance for observations. Climate change today is driven by two large human-made climate forcings: greenhouse gases (GHGs) and aerosols (fine airborne particles, which result in visible air pollution when present in sufficient amount). Aerosol climate forcing results in part from the effect of aerosols themselves on incoming solar radiation, but mainly from the effect of aerosols as condensation nuclei for cloud drops. Increased aerosols result in smaller cloud drops (because the supply of water vapor is limited), which in turn causes clouds to be brighter (higher reflectivity) and longer lived (thus increasing global cloud cover).

Measurement of aerosol climate forcing thus requires precise global monitoring of cloud and aerosol microphysics. Whether NASA would measure the aerosol climate forcing was a contentious issue beginning in the late 1980s, primarily because the observations required sampling of the seasonal and diurnal cycles of cloud cover that could best be achieved from a pair of relatively inexpensive small satellites, which we dubbed Climsat. This proposal was deemed by some to be competitive with NASA plans for its Earth Observing System, which was focused on large platforms in near-polar orbit. As a result, the aerosol climate forcing has not been monitored and aerosol forcing is, in effect, a free parameter in climate models.

Absent accurate knowledge of the aerosol forcing, a wide range of climate sensitivities are consistent with observed global warming during the past century. A small climate sensitivity requires rather little aerosol cooling to match observed warming. However, a larger climate sensitivity combined with greater aerosol cooling is also consistent with observed global warming. In *Pipeline*, we obtain an indirect inference on aerosol climate forcing via well-defined knowledge of climate sensitivity (from paleoclimate) and accurate satellite measurements of Earth's energy balance. Especially because of the absence of monitoring of the aerosol climate forcing, it is crucial that the precise measuring of Earth's radiation budget continue. If NASA is not going to make such plans, it is crucial that ESA (the European Space Agency) take up the challenge. Otherwise, today's young people truly will be "up sxxt crick without a paddle," in any efforts to understand continued global temperature change and guide climate and energy policies.

Pipeline, via paleoclimate analyses, reveals that climate sensitivity is higher than IPCC's best estimate of 3°C for doubled CO_2. This is a double whammy, because the higher sensitivity implies that the aerosol effect is underestimated by IPCC. Thus, in addition to higher climate sensitivity, the Faustian payments that come due as we clean up air pollution are greater. In the absence of measurements of aerosol climate forcing, the magnitude of the observed change of Earth's radiation budget in the regions of heavy ship traffic indicates that aerosol models are likely underestimating the effect of aerosols on clouds.

Guidance for climate policy. Guidance for global energy and climate policies is also hindered by over-reliance on models. As a result, science has not informed policymakers well about the prospects for ongoing climate change, as evidenced by claims that targets for limiting global warming can still be achieved via realistic phasedown of emissions. This fiction is maintained via the combination of unrealistic assumptions in Integrated Assessment Models and low-sensitivity climate models. The conclusions of that approach are falsified in *Pipeline* by comparison of results from those models with ongoing real-world observations.

The reluctance of IPCC, the body providing scientific guidance to the United Nations, to provide technical advice is disappointing. As one example, note that, buried in the thousands of pages of IPCC reports is the conclusion that nuclear power has the smallest carbon and environmental footprint among the major sources of energy. It has long been understood by energy experts that, in the absence of nuclear power, fossil fuels will provide the 24/7 dispatchable electricity generation essential to complement intermittent renewable energy. The hesitance to offer such technical advice may be related to scientific reticence.

Scientific Reticence. This topic is discussed in *Pipeline*. I must finish this communication this morning, so I conclude with the example provided by the *Ice Melt* paper. The concluding words of the title of the *Ice Melt* paper were "…2°C global warming is highly dangerous." The paper had been heavily peer-reviewed by four referees and by the wider community via the open review process. One of the four referees – an IPCC lead author – had strong objections to the paper, but he was overruled by the other three referees and the editor.

However, the editorial board intervened, insisting that the paper could not be published unless we changed the last words of the title from "…2°C global warming is highly dangerous" to "…2°C global warming could be dangerous," an almost meaningless conclusion.

The editor – an exceptional scientist – agreed with our position, but was unable to prevail. I wrote an explanation of the public's understanding of the word "dangerous": if a person looked down a dark street and saw a bunch of guys loitering and seeming to hold weapons, would that person consider that street to be dangerous and take a different route home, even though there was not 100 percent proof that he would be assaulted if he went down that street? The editor then reported to me, in disappointment, that, if I included that explanation in a letter to the journal, we would not be able to publish *Ice Melt* in the journal (all correspondence between an author and the journal is publicly available). We decided to submit to this demand (omitting the discussion of what "dangerous" means to the public in our official communication) because of a prior similar experience with another journal (which resulted in a one-year delay of publication, as we had to start the review process over with a different journal). Such is the nature of the scientific reticence that has infected our scientific community.

In *Ice Melt*, we used the three-prong analysis to show that continued high emissions would cause shutdown of the North Atlantic Overturning Circulation (AMOC) and the Southern Ocean Overturning Circulation (SMOC) this century, possibly by mid-century, and sea level rise of several meters on the 50-150 year time scale. In *Pipeline* we reveal how the reticent community, with full reliance on models (that tend to be unrealistically insensitive to freshwater injection) alone, could manage to dismiss this result, and, instead, conclude that there was less than 1 percent chance of shutting down AMOC, even with high GHG emissions.