DRAFT

Solar variations, cosmic rays, clouds, and climate change
or
- a different approach to understanding global warming

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The present summary highlights some of the results of the research in solar activity variations and climate change which were obtained at the National Space Institute during the last 10 years. This research has been carried on in parallel with the climate research activities monitored and reported by the International Panel of Climate Change (IPCC), but without too much appreciation from IPCC so far.

The IPCC was established with the specific objective to assess the contribution from human activities to the recent global warming and provide the scientific basis for possible political measures to manage the climate change issue. The IPCC was not intended to carry out specific research to provide the answers but rather to examine the existing research results and to evaluate the sometimes conflicting results. IPCC does not itself fund scientific research but its conclusions and recommendations have had a big impact on the direction and funding of climate research through the National and International funding agencies. An example is the decision by the IPCC at its meeting in Guangzhou in January 1992 not to support a proposal from the Danish delegation to include in the list of poorly understood climate processes the role of solar variability.

In contrast to the political rationale of the IPCC effort, the Danish research – like any basic science – started with curiosity and a genuine interest to understand the natural climatic processes. Long-term observations as well as historical and geological records clearly demonstrate that climate has always been changing, sometimes with significant implications for the human population. Such changes are not only related to the ice ages, which are commonly believed to be caused by changes in the Earth's orbit around the Sun, but do also occur during shorter time intervals as for example the term "the Medieval Warming Period" or "the Little Ice Age" indicate.

The different approach of the politically driven IPCC initiatives compared to basic research activities is perhaps most clearly manifested in the assessment of historical global temperature variations compared to recent global warming. Mann et al. (1998) published a global temperature reconstruction during the last 600 years that deviated remarkably from all previous temperature reconstructions by emphasizing the global temperature rise in the last hundred years while reducing the temperature variations during the remaining part of the series.

This particular global temperature reconstruction, the "hockey stick graph", was heavily promoted by IPCC in spite of the fact that it deviated significantly from previous temperature reconstructions and in spite of the fact that it also in its conclusions was at odd with a lot of evidence of a period of rather cold climate in Europe during the 17th century also supported by direct bore hole measurements in the Greenland Ice Cap (Dahl-Jensen et al., 1998). One main reason for this promotion was obviously that it fitted very well with the results of numerical climate models, which had difficulties reconstructing past climate variations of the size that the available temperature reconstructions had indicated. Later, however, the IPCC downplayed the importance of the hockey stick graph realizing several papers criticizing the methodology and the results (references?).

Whereas the numerical climate models were not able to explain the historical record it turned out that the climate variations documented in historical and in geological observations were consistent with simultaneous solar activity variations. C-14 measurement demonstrated a high solar activity during the Medieval Warming Period characterized by high temperatures in Green land and Europe whereas the Little Ice Age that followed was characterized by intervals of very low solar activity. The most well-known among these, the Maunder minimum, was during the time of notoriously cold winters in Europe. But also in other areas of the world a clear connection between solar activity and climate parameters have been identified as for example shown in the stalagmites in caves in Oman, which show a remarkable correlation between solar activity and the ratio between the O-18 and the O-16 isotopes in the stalagmites during more than 3000 years (Neff et al., 2001).

I should be emphasized, however, that the research in the Danish group was not primarily intended as a contribution to the recent global warming discussion. Rather, the scientists were occupied with finding a physical mechanism, which was able to explain the relationship between solar activity and climate variations. Working at an institute dealing with space science research it was natural to take advantage of their expertise regarding physical processes in space in connection with an issue highly relevant to society, in particular because such expertise was not obviously apparent in the community carrying out the scientific research, which was in the heart of the IPCC agenda.

Climate and changes in climate rely on complex physical processes determined primarily by the difference in energy received from the solar radiation and the energy radiated away from the Earth. These processes involve the spectrum of the solar radiation, the composition of the atmosphere, including clouds, and the Earth's surface properties determining the reflection of incoming radiation. It is important to realize that all these factors play a role and that the estimation of the anthropogenic contribution cannot be done properly without an understanding of the natural climate processes that have been in play forever, and are still in play.

This has been partly recognized by IPCC. In 1992 one of the main statements was that the temperature increase during the last century was "broadly consistent" with the increased level of CO2 in the atmosphere. In 2001 the statement was revised to only relate to the last 50 years, realizing the potential effect of natural climate variations

during the first part of the last century, which very closely followed the solar activity as demonstrated by Friis-Christensen and Lassen (1991). In an updated figure Lassen and Friis-Christensen(2000) did realize that the recent years (after 1985) demonstrated a rise in global surface temperature not predicted by solar activity indices. Lockwood and Froehlich (2007) came to the same conclusion. One obvious interpretation, of course, would be that human influence was finally standing out and that the last 30 years of global surface temperature rise was in fact due to the increased amount of CO2 in the atmosphere. This is a tempting argument for those persons just concerned with demonstrating the anthropogenic effect. But for a physicist it is not at all sufficient unless a comprehensive understanding of the physical processes is reached.

One of the least understood processes in climate research is the formation of clouds. Clouds, on the other hand, is also one of the most efficient means of changing the radiation from the Sun reaching the Earth. Svensmark and Friis-Christensen (1997) demonstrated that the global cloud cover is well correlated with the cosmic ray flux, which again is modulated by the solar activity. Later, March and Svensmark (2000) refined the analysis with additional data and found that it was actually the low clouds, which were correlated with the cosmic rays. This was an important result because it gave a hint regarding the possible physical mechanism, which could explain the correlation. If only low clouds are influenced it has to be a mechanism involving liquid water as opposed to high clouds, which consist of ice particles.

But a correlation is not sufficient. The physical mechanism has to be found and explained and possibly used to make predictions, which is the ultimate test of a physical theory. Such tests are most conveniently made in a laboratory where the physical parameters may be varied and control measurements can be done. At the National Space Institute one of the clean rooms was turned into a cloud chamber where the first steps in the formation of clouds or water droplets could be simulated. Water droplets form on cloud condensation nuclei, which are formed in a physical process starting with the creation of ultra-fine aerosols. The Danish group wanted to experiment with the role of ions – electrically charged atoms – in such a process. Since most of the atmospheric ions, in particular over the oceans, are formed by the cosmic rays, an effect of ionized particles on the creation of ultra-fine aerosols would indicate that the cosmic rays are the missing link between solar activity variations and climate. Svensmark et al. (2006) were actually able to demonstrate that such an effect does exist in the laboratory, and through a mechanism not yet described in the literature.

The laboratory experiments indicate that important physical processes related to the formation of clouds are not included in the current numerical climate models, which are used to predict future climate changes. Perhaps this missing component in the climate models is the reason why the temperature trend in the troposphere is less than the trend in the surface temperature record in spite of the fact that current climate models estimate that the tropospheric trend should be twice as large as the trend in the surface temperature (se figure ?). This argument is further supported by the fact that the reduced trend is apparent both in the satellite microwave sounding observations and in the radiosonde measurements from balloons. Finally, a complete climate model should also be capable to

simulate the clear 11-year solar activity cycle effect in the tropospheric measurments as well as in the uppermost (mixing) layers of the oceans (see figure ?) from Svensmark and Friis-Cristensen (2007).

The amount of global warming that can be attributed to anthropogenic origin may well be significant but at the moment the estimate of the anthropogenic global warming is relying on climate models that are still not capable to explain some of the most fundamental and observable processes in the atmosphere. These models should be taken with a grain of salt, and in spite of what is the current public opinion, the science regarding global warming is far from done.

This does not mean, however, that politicians and the public are not supposed to make decisions. Political decision may not always allow a full and comprehensive basis for the decision. Such are the conditions and the scientists are not necessarily in a better position to make political decisions than the layman. The problem only arises if the decision makers are not fully informed about the conflicting views of the scientists and the uncertainty of the predictions that follow from that.