The role of Sun in climatic change:

The Sun and Us

by

Alex Kirby, BBC Environment Correspondent

I'm not a scientist, so this won't give you the scientific arguments for solar influences on our climate. It's more a sort of idiot's guide to the subject. It describes the thinking of the IPCC about the Sun's influence on our climate. Paal will tell you why he thinks the IPCC needs more information before it can be certain about what's happening and why. It's an important area of debate, particularly with the climate conference going on in Marrakesh now. Some people argue that climate change is entirely natural, and that there is nothing we either can or need to do about it. So it is worth trying to see what part the different influences on the climate do actually play.

What do we know?

We know the average temperature at the Earth's surface has warmed by 0.6 degrees Celsius since 1860. The 1990s were the hottest decade of the last century, which the IPCC says warmed more than any other period in the last thousand years in the northern hemisphere. Global sea levels have risen by between 10 and 25 cm over the past century, and are set to go on rising for several centuries, because of the capacity of the oceans to store heat. We know that greenhouse gases are accumulating in the atmosphere -- a 32% CO₂ rise since 1800, near the start of the Industrial Revolution, and a doubling in methane levels since 1900. The rate at which the CO₂ is increasing is the highest for at least 20,000 years. Present CO₂ concentrations have not been exceeded for at least 420,000 years, and possibly not during the last 20 million years. Sir John Houghton, the British scientist who co-chairs the IPCC's working group one, on the science of climate change, has said the rate of warming is far greater than it has been for the last 10,000 years.

What does this tell us?

The IPCC says it expects various possible consequences if we go on as we are. It predicts that temperatures could conceivably rise by between 1.4 and 5.8 degrees by the end of this century, though a study published in July suggested the likeliest range is an increase of between 2.4 and 3.8 degrees. For comparison, we are now about five degrees warmer than in the last Ice Age, just over 10,000 years ago. Global sea levels are predicted to rise by between 20 and 90 cm this century. In Europe, and perhaps in other parts of the world as well, wet areas will become wetter and dry ones drier. Storms are likely to increase in frequency and ferocity. There could be what are called "non-linear" consequences -- a sudden flip from one
stable state to another very different one, or perhaps changes to the Gulf Stream. There is evidence from glacier ice cores that climatic changes can occur gradually, a few degrees over centuries, or very abruptly, with shifts of from six to ten degrees Celsius in less than two decades. There may be feedback mechanisms which mean that the warming of the atmosphere triggers phenomena which themselves increase the warming: one possible example is the thawing of the carbon and methane locked up in the Arctic permafrost. The periodic El Niño weather disturbance in the Pacific may become more frequent, though the relation between it and climate change is still not clear.

So is climate change all our fault? Are we at least the main cause?

Well no -- something else we know is that the climate is an unstable system, that it's always changing because of its natural variability. All we appear to be doing is adding to that variability by pouring pollution into the atmosphere. Obviously, the IPCC says, if we stopped or reduced our contribution to what's happening the climate would be less variable, and that might be good for the Earth. We are one factor among several, even if we are increasingly the most influential factor. One of the chief causes of natural climate variability, which we shall always have, is the Sun. The Sun is important because it's big and full of energy -- a million times larger than the Earth, and producing enough energy each second to power the US for 9m years. It would be difficult for it not to affect our climate somehow.

How does the Sun affect us?

The most obvious way is directly, by the heat that reaches the Earth -- the Sun's radiance. Although this is significant -- significant enough to make life possible here for us and for all other species that have ever lived on Earth -- it's not thought to vary enough to explain the extent of global warming that is happening now. But the Sun does several other things apart from simply heating the Earth directly.

One is to emit powerful winds when it is unusually active -- and these winds protect the Earth's atmosphere from galactic cosmic rays which play a part in helping to create clouds. Clouds are one of the big unknowns in climate change. They can reflect incoming solar radiation back into space, keeping heat out of the atmosphere. Equally, they can prevent the escape of radiation from the Earth's surface, keeping heat in. We don't know exactly what clouds do, but we do know they are important. At least we can say that if the Sun is somehow affecting cloud formation on Earth, then it is having some indirect effect on our climate.

Another effect is the observed influence of the Sun's ultra-violet light on the photochemistry of atmospheric gases such as ozone. This may also affect the climate, even if again we cannot yet say how. The interaction between global
warming and ozone loss is complex, and there is *some* evidence that each is worsening the other.

There's thought to be yet another possible way in which the Sun may be exerting an indirect effect on the Earth's climate, this time through its magnetic flux. UK scientists found in 1999 that the magnetic field between the planets had increased in strength by 40% since 1964. The field is caused by the solar wind, a stream of particles given off by the Sun which fills the solar system. Evidence from before the space age suggests that the interplanetary magnetic field is 2.3 times stronger than it was a century ago. Scientists are pretty certain that the cause is a more energetic Sun, but they're not sure what it means for us on Earth.

But one scientist, Professor Eugene Parker, of the Laboratory for Astrophysics and Space Research at the University of Chicago, believes that it might explain global warming. He points out that the increased solar activity has occurred in parallel with an increase in CO₂ in the Earth's atmosphere, and he thinks that may be no coincidence. His theory is that it was the Sun's increased activity that caused the Earth's temperature to rise, and that that in turn warmed the oceans. They were then able to absorb less CO₂ from the atmosphere, and it and the other greenhouse gases then built up there. So according to Professor Parker's theory, it's not people that are responsible for causing global warming by burning fossil fuels. It's the Sun that's responsible, for stopping the oceans from doing their job of absorbing the gases.

There are other pointers to the Sun's influence on the Earth's climate, even if they are not conclusive. One example is the little ice age during the 17th century, a time when very few spots appeared on the Sun's surface. Earlier, starting in the 12th century, the Earth experienced a spell of warmer than average global weather, known as "the medieval maximum". That was a time, astronomers believe, when the Sun was slightly brighter than usual. A review published this week by the Center for the Study of Carbon Dioxide and Global Change of research on western Norway's temperature history over the last 5,500 years concluded: "The authors' results clearly establish the reality and importance of the Medieval Warm Period in the North Atlantic region. Although certain climate alarmists continue to claim this most recent high-temperature excursion was not very striking, the data of this meticulous study strongly suggest it was warmer during this specific time period than it was during any other multi-century period of the last five millennia."

Some people are so convinced that the Sun can explain the entire climate change phenomenon that they dismiss the work of the IPCC altogether. One of them is a British weather forecaster, Piers Corbyn, who said: "Particles and magnetic effects from the Sun are the decisive influence that controls world temperatures. The evidence can be seen in the graphic representation of geomagnetic activity plotted against world temperatures. The two correlate very closely."
So those are the ways, or at least some of the ways, in which the Sun appears able to affect the Earth's climate. But although it can have those effects, we shouldn't assume that it necessarily does -- or at least that it does so today.

What does the IPCC think is happening?

The IPCC believes that the Sun used to be a major league player in affecting the Earth's climate, but that its importance has diminished. Choosing its words carefully, it says: "We conclude that climate forcing [in other words, climate change] by changes in solar irradiance and volcanism [the contribution from volcanic eruptions] have likely caused fluctuations in global and hemispheric mean temperatures. Qualitative comparisons suggest that natural forcings produce too little warming to fully explain the 20th century warming. The indication that the trend in net solar plus volcanic forcing has been negative in recent decades makes it unlikely that natural forcing can explain the increased rate of global warming since the middle of the 20th century." In other words, the IPCC believes the Earth is warming up too rapidly for the Sun to be responsible on its own for what is happening. Therefore, it argues, what we are doing must be an increasing factor in the equation.

In fact the IPCC is becoming more certain that we bear a lot of responsibility. In 1995 it said that "the balance of evidence suggests a discernible human influence on global climate". But by this year it was saying something much stronger, that human activities have "contributed substantially to the observed warming over the last 50 years". It said: "There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities." Its Third Assessment Report, published last January, estimated the warming caused by changes in solar energy since 1950 at about one-fifth of that attributable to CO₂, and concluded that "natural agents have contributed small amounts to warming over the last century.

Many other scientists agree with the IPCC's general argument, that human influences now count for more and the Sun's effects for less, but they sometimes differ on the timing of the change. One example is a study by three US scientists, published in the magazine Science in November 1998. They analysed 115 years of global temperature data, and compared the result with the output from two leading computer climate models.

The implication of their findings, the authors said, was that the 20th century's warming trend had overpowered the climate's natural variability. Significantly, they said variations in solar output over the century could have been large enough to affect some long-term trends. They found that global temperature rose sharply from about 1900 to 1940, and then levelled off until the 1970s. Then it began another warming spell which accelerated during the nineties.
After doing a separate experiment with a simpler climate model to establish the role of the Sun, the scientists concluded: "Solar forcing alone is insufficient to explain the behaviour of the observed temperature data." But combining the Sun's effects with changes in greenhouse gas levels, they found, meant they produced a result they thought was more credible. They said their results "imply that both anthropogenic activities [activities with a human origin] and solar forcing have significantly affected global climate".

The following year the magazine New Scientist reported a study by two Danish meteorologists. Nine years earlier, in 1991, one of them, working with another colleague, had found a strong correlation between the length of the solar cycle and temperature changes in the northern hemisphere. The relationship they identified appeared to account for almost 80% of the measured temperature changes. But the study the two published in 2000 found that, while the solar cycle still accounts for about half the temperature rise since 1900, it fails to explain a rise of 0.4 degrees C since 1980. One of the meteorologists said: "The curves diverge after 1980, and it's a startlingly large deviation. Something else is acting on the climate." He and his colleague say that that something "has the fingerprints of the greenhouse effect". They conclude: "We're now seeing that the Sun plays a role, and something in addition to the Sun. Maybe that will help people to see there is room for both."

In what proves to be support for the Danish findings, a British scientist, Professor Mike Lockwood, of the Rutherford Appleton Laboratory near Oxford, looked at the Sun's total power output, the solar irradiance. Although that rose during the 20th century by only a very small amount, he said -- 0.1% of the total output -- it could still have a marked effect on the Earth's climate. By comparing solar irradiance figures with the surface temperatures on the Earth since 1900, he estimated that all of the global warming that occurred up to 1920 could be attributed to an increase in solar output. Between 1930 and 1970, he said, only half the amount of warming could be credited to the Sun. And from 1970 onwards the proportion came down to one-third, suggesting that the human contribution to climate change was increasing -- and almost certainly still is.

I spoke to Professor Lockwood just over a year ago for an article I was writing, and what he said then remains relevant now. He told me: "I have doubts about how low some people want to keep the solar contribution. Over the whole of the last century, I'd say it was perhaps about 40-50% of the total. But the important point is that most of that was in the first 50 years. From 1970 to now the main influence has been human activity, and that's rather scary. The anthropogenic effects are now kicking in for real. And after all, the amount of carbon dioxide and methane in the atmosphere should have had some effect, though there are still a lot of unknowns."

Since 1970 global mean temperatures near the Earth's surface have been increasing at 0.2 degrees C a decade. That rate of warming is predicted to continue.
over the next few decades. If it does, and if nothing changes, the world looks likely to be two degrees warmer by the end of this century than it is now, and possibly more.

So there you have it. It was the Sun in the earlier part of the last century. It's us now. At least, that's the official view. I'm not a scientist, and I have to take what the scientists say on trust -- I'm in no position to try to prove or disprove their assertions. But one thing that does seem clear from the debate about what's happening to the climate is that there are still a lot of unknowns, as Professor Lockwood put it, both about what really is happening and about what's making it behave the way it is. So the thought I want to leave you with this morning is just this: we do need to do the research that will clear up what we don't know as soon as we can. There's a lot at stake.

*Alex Kirby is environment correspondent for BBC News Online (http://news.bbc.co.uk). He is at alex.kirby.01@bbc.co.uk.*