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The greening of the North: real, and caused by climate change

Twenty years of satellite observations have indicated a “greening” trend in northern regions of the northern hemisphere (boreal regions). Scientists at Max Planck Institute for Biogeochemistry (MPI-BGC) in Jena, Potsdam Institute for Climate Impact Research (PIK), Lund University, Boston University and the Le Laboratoire des Sciences du Climat et l'Environnement (LSCE), Paris, have developed an advanced global ecosystem model showing that the trend is just as would be expected due to the warming climate (*Science* 31st May 2002).

Some years ago Ranga Myneni and his colleagues at Boston University published a paper in Nature apparently showing a “greening trend” in the boreal regions. The finding was based on satellite observations, and many scientists were sceptical about it because of problems of instrumental “drift” that could possibly make any observed long-term trend unreliable. The Boston team, however, persisted in their efforts to re-analyze the data, taking into account all possible anomalies. The trend would not go away, and it has become clearer with time as new data have come in.

A possible cause was always obvious: weather station records from the North have reported a steady warming (by about 0.4 degree per decade), which is now generally attributed to the increasing greenhouse effect. Warming in the North might be expected to produce “greening”. However, it was not trivial to connect the weather station data to the satellite data to find out whether there was a quantitative correlation between the two trends. Although computer-based numerical models of the physical climate have been used for three decades to analyze the possible consequences of increasing greenhouse gas concentrations, comparable global models of ecosystem dynamics are a much more recent development.

Now, a major activity of the Global Ecology research group at MPI-BGC, under the leadership of Prof. Colin Prentice, is the ongoing development of a leading global terrestrial ecosystem model. The model is called LPJ, after the three research groups (led by Prof. Colin Prentice at MPI-BGC, Prof. Wolfgang Cramer at PIK; and Prof. Martin Sykes at Lund University) that participate in the model development consortium. The basic idea of the model is to integrate current

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knowledge in separate fields (plant physiology and biophysics, terrestrial ecology and hydrology), to simulate the interaction of processes with different time constants (minutes to years), and to use all possible sources of information – including satellite observations – to evaluate and refine the model. The new results, published in Science on 31 May 2002, are the product of a co-operation between the LPJ and Boston teams – spearheaded by Dr Wolfgang Lucht, a young scientist at PIK with close links to the remote sensing community – in which month by month climate observations from across the entire boreal zone were used to drive the LPJ model. It was found that the expected changes in leaf area index during each growing season and (most importantly) from season to season, based on climate data, fitted remarkably well to the satellite data. Two decades of satellite observations showed that spring has advanced by about a week, and summer maximum leaf cover has increased as well. The model results showed that these trends correspond quantitatively to what should be expected, based on the warming that has occurred. The only plausible explanation for this agreement between two fully independent sources of information is that the remotely sensed trend is real, and that it was caused by the changing climate.

With a model such as LPJ, it is also possible to perform sensitivity tests to isolate the key factor causing a given effect. It was found that the trend was caused entirely by temperature. It was not caused by physiological effects of increasing carbon dioxide concentration on plant growth (which are likely to be much more important in warm climates than in cold climates), or by the increasing rain- and snowfall that has accompanied the increase in temperature.

One major event temporarily interrupted the trend: the 1991 eruption of Mount Pinatubo in the Philippines, whose fallout of volcanic aerosol produced a 0.5 to 1 degree average cooling – as well as spectacular sunsets! – in northern high latitudes during 1992-3. Again, satellite data had already shown an interruption to the greening trend. And once again many scientists were sceptical because the volcanic aerosol itself affects the performance of the space-borne instruments. But in this case too the LPJ model results showed the same thing as the satellite observations – a short-lived dip in the trend, which was promptly resumed after the volcanic dust had settled.

The Pinatubo eruption had another effect too, which greatly surprised carbon cycle scientists when it occurred: The rate of increase of carbon dioxide in the atmosphere suddenly slowed down for two years. A full explanation for this (which probably involves temperate and tropical regions as well) has not yet been found. It was possible to engage the LSCE team, which has been using advanced mathematical tools to analyze the small variations in carbon dioxide concentration that are observed between different measurement stations across the globe, in order to infer the changing patterns of regional sources and sinks of carbon dioxide on land and at sea. Their results showed that during the “Pinatubo years” the land at high latitudes was taking up a great deal more carbon dioxide than usual.

The LPJ model results showed exactly the same thing. Even though the growing season was shortened and photosynthesis reduced, the cooler growing season meant slower decomposition of organic matter in the soil. This was the dominant effect of cooling for the net carbon exchange of the land in high latitudes, and it contributed to the slowing of the carbon dioxide growth rate at a global scale.

These results represent a “coming of age” for ecosystem modelling. They clearly demonstrate the value of collaboration between observational and theoretical communities (which has often been deficient in global change research). Much ecosystem modelling up to now has been aimed at forecasting the impacts of future climate change, but in this aspect models show large differences. Thus, models need better evaluation, and the only way to do this is by making systematic comparisons between model predictions and observations referring to the present and past.

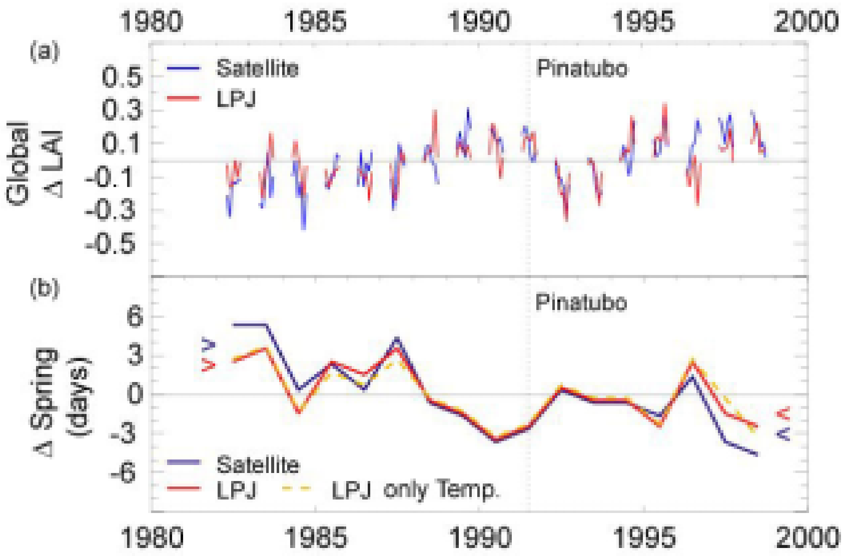

Fig.:* (a)** *Differences of leaf area index (LAI) in the global boreal zone from the long-term average for each month, as shown by satellite data and as simulated with the LPJ model. (Leaf area index is the ratio of total leaf area to ground area.)* ***(b) *Change in the timing of spring budburst in the global boreal zone, as differences from the long-term average for each year, shown by satellite data and simulated by the LPJ model. The dashed line shows an LPJ model run in which only temperature was varied from year to year.*

Figure: Max Planck Institute for Biogeochemistry

The results have implications beyond academia. We have shown that the biosphere is indeed changing, due to a climate change that most likely is a direct consequence of human activities (principally in the industrialized countries). The warming and "greening" of high latitudes, if they continue, will have mixed effects from the point of view of the societies involved. The potential for forestry and agriculture in northern Canada and Siberia will improve, but Arctic ecosystems and species, and the indigenous cultures that depend on them, will be threatened by the invasion of plant and animal species from the south.

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