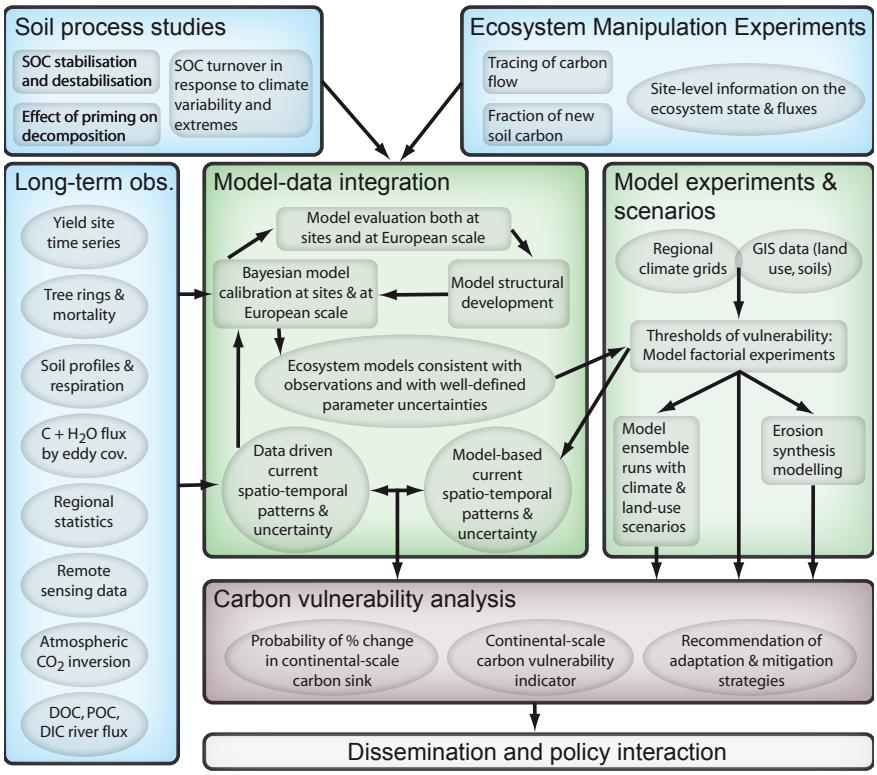
Michael Bahn, UIBK (Innsbruck, Austria): Drought experiment at CARBO-Extreme site Stubai, Austria, June 2009

Flurin Babst, WSL (Birmensdorf, Switzerland): researchers at fieldwork – sampling tree rings in Abisko National Park

The evolution and vulnerable nature of carbon sinks

Main image: Marcel van Oijen, CEH-Edinburgh (U.K.): Drought in Mediterranean soil, island of Milos, Greece

While it is predicted that the biosphere will continue sequestering carbon in the first half of this century, uncertainty remains over the likely impact of climate variability on the carbon cycle. We spoke to **Dr Markus Reichstein** about his work assessing soil carbon vulnerability



The current ability of Europe's terrestrial ecosystems to soak up between 7 to 12 per cent of the continent's overall fossil fuel emissions takes on real importance in the context of climate change; however, little is known about the impacts of climate variability and weather extremes on the future evolution and vulnerability of Europe's terrestrial carbon sinks. CARBO-Extreme, a project funded by European Community's 7th Framework Programme, wants to overcome this knowledge gap. "We aim to better understand the effect of climate variability and extremes on the carbon balance of European ecosystems. In future there are likely to be more extreme events like the European heatwave of 2003. Such hotter and drier summers can change ecosystems and their thermo- and carbon-dynamics quite dramatically, with a strong influence on the overall carbon balance," says Dr Markus Reichstein, the project's overall coordinator. Based himself at the Max Planck Institute for Biogeochemistry in Germany, Dr Reichstein says the nature and scale of modern environmental problems demands international collaboration. In CARBO-Extreme 25 partner institutions from across the continent are collaborating in three main components – the observation, modelling and assessment of soil carbon vulnerability (cf. Figure above). "There are a lot of different aspects to the question of the carbon balance and what affects it, and so we have to combine very different data streams and methodological approaches to get an answer," he points out. "This includes flux measurements, where we directly measure the exchange of carbon and water between the ecosystems and the atmosphere. We also look at tree rings and data that has accumulated over long timescales, this allows us to look at extreme events and climate variability in general over the last century."

> "We aim to better understand the effect of climate variability and extremes on the carbon balance of European terrestrial ecosystems. This work was stimulated in large part by the European heatwave of 2003"

Historical perspective

Historical perspective is crucial to understanding our current environmental context. Without knowing how and why our climate changed in the past we cannot understand what is going on today, and will much less be able to develop models to predict how the carbon cycle is likely to develop in future. While biogeochemical and biophysical models have already been developed, they do not yet include the relevant processes with regard to climate variability and extreme events, something of which Dr Reichstein is well aware. "The challenge is to improve existing models with the respective observations – on the one hand to include more of the important processes in the models, and on the other to constrain the models with the observations," he explains. These models are based on analysis of physical mechanisms, with the project focused in particular on analysing carbon sink vulnerability with respect to water availability and temperature. "These two are actually interlinked issues, and that makes the overall problem critical, because quite often what we call regional feedbacks affect the carbon cycle. When it gets drier there is less moisture in the soil and so less evaporation. That means there is less cooling, because if water evaporates it gets cooler. Similarly if it gets drier there is also feedback in that it gets hotter and drier; it's actually been shown that this kind of feedback exists on the regional scale," says Dr Reichstein. "We have partners doing experiments in locations from northern Europe to the southern Mediterranean, and their knowledge will be included in the models" stresses Dr Reichstein. "Our goal is to simulate realistic regional scenarios with squares of 25 kms x 25 kms based on mean changes in temperature and precipitation. The results will be presented as maps for countries and some regions, as well as for different sectors like forestry and agriculture," continues Dr Reichstein. "In the regional scenarios the year-to-year variability – including extreme climate fluctuations – are simulated, from which we can then see the effect of strong variations such as extremely dry conditions

At a glance

Full Project Title
CARBO-Extreme

Project Partners
Details can be found on the project website: www.carbo-extreme.eu

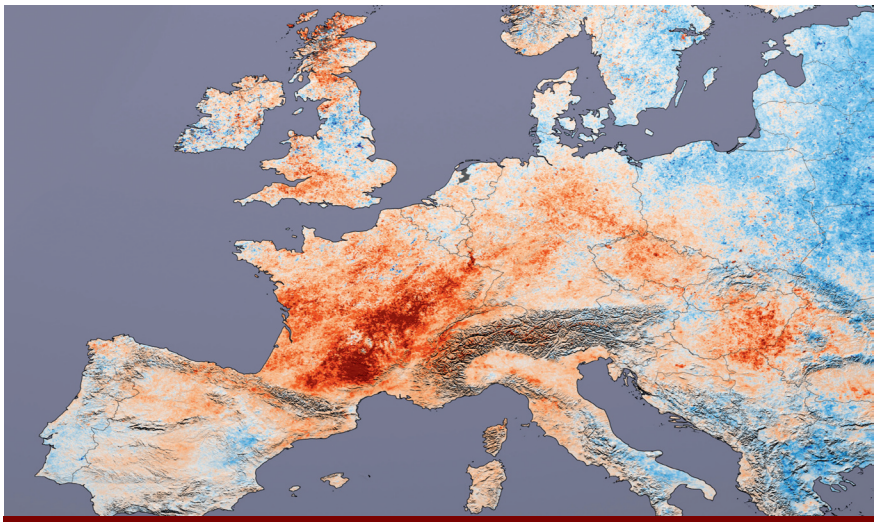
Project Objectives
Obtain a better predictive understanding of terrestrial carbon cycle responses to climate variability and extreme weather events for European forest, grass- and peat-land and arable ecosystems. Identify the most vulnerable carbon pools and processes to climate variability and extreme events. Map the most likely trajectory of carbon pools in Europe over the 21st century and associated uncertainties introduced by model assumptions and setup

Contact Details
Project Coordinator,
Dr Markus Reichstein
Biogeochemical Model-Data Integration Group (MPRG)
Max-Planck-Institute for Biogeochemistry Jena
Hans-Knöll-Str. 10
D-07745 Jena
T: +49 3641 576273
F: +49 3641 577200
E: markus.reichstein@bgc-jena.mpg.de
W: www.carbo-extreme.eu

Dr Markus Reichstein

Project Coordinator

In 2006 Markus Reichstein established the Biogeochemical Model-Data Integration Group at the Max-Planck-Institute for Biogeochemistry in Jena.



TERRA MODIS (MODerate resolution Imaging Spectroradiometer) derived land surface temperature data of 1km spatial resolution The difference in land surface temperature is calculated by subtracting the average of all cloud free data during 2000, 2001, 2002 and 2004 from the ones in measured in 2003, covering the date range of July 20 – August 20. Image by Reto Stöckli, Robert Simmon and David Herring, NASA Earth Observatory, based on data from the MODIS land team

over longer periods or extremely low or high temperatures that might cause tree mortality, and then go on to have a long-term effect on the carbon cycle that gradual change might not have had."

This is backed up by recent studies which clearly show that climate variability and extreme weather events can undo the effects of several years of an ecosystem acting as a carbon sink. This is a real concern, particularly in the light of the EU's stated climate protection goal of stabilising CO_2 greenhouse gas concentrations, an objective which involves not only reducing emissions of greenhouse gases, but also improving our understanding of key terrestrial ecosystems. "Forests tend to be carbon sinks at the moment, while agricultural areas are neutral. What we are looking at is how vulnerable these sinks are. If droughts and other stresses on the climate become more frequent then these sinks might disappear, or even turn into sources, just through the mortality of forests. In fact this has already happened as a result of the 2003 heatwave," warns Dr Reichstein. This is an event still fresh in the public mind (cf. Figure above), underlining the immediate relevance of carbon cycle research. Indeed, further extreme weather events occurred as recently as 2006 and 2007, and research into their effects on the carbon cycle presents a complex picture. "In 2006 it was also very hot in certain areas but it wasn't as dry as 2003, which is why there weren't such strong effects on the carbon cycle," explains Dr Reichstein. "It was very different in 2007, which was a warm year as the temperature was consistently above average - but not a hot one. The particularly warm autumn and winter caused vegetation to develop and flower very early in 2007. That had quite a positive effect on the carbon cycle as a lot of carbon was sequestered. So extreme weather doesn't automatically have a negative impact on the carbon cycle, extreme droughts are the biggest problem."

Environmental policy

These findings hold clear political relevance in terms of environmental policy and EU wide adaptation and mitigation strategies, as well as scientific relevance with regard to climate modelling. A stakeholder meeting will be held in April 2010, at which the presentation of the first project's results and its further development will be discussed.

Until now much of the global attention has been focused on reducing greenhouse gas emissions, and while this is clearly crucial to stabilising the CO_2 concentration of the atmosphere, extreme events and their impacts on terrestrial ecosystems also have a key role to play. "We are continually trying to improve the models by incorporating more observed data. This will then form the basis for model simulations, and hence predictions based on those observations" explains Dr Reichstein. "As new mechanisms involved in the carbon cycle were only identified relatively recently, there's still a lot of work to do, and the results will definitely be of interest to the global climate modelling community and stakeholders addressing the topic of climate change" ★