CARBO-Extreme

The terrestrial Carbon cycle under Climate Variability and Extremes – a Pan-European synthesis

Publishable summary 3rd reporting period

Grant Agreement N°226701

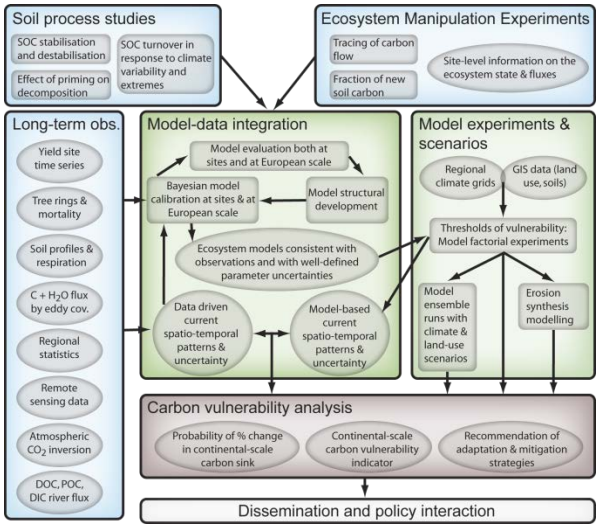
Summary description project context and objectives

One of the major unknowns in climate modelling and climate impact research is how the terrestrial carbon cycle reacts to climate variability. Climate variability is occurring across a large range of time scales, from seconds to millennia; however the focus of attention has mainly been on slow, gradual changes of climate, for instance rising temperature means and CO_2 concentrations. Climate variability and extremes will play an important role for the estimation of future impacts of climate change, but they have not so far been sufficiently accounted for in modelling and experimental studies. This creates to a critical knowledge gap which is noticeable, for example, in the ongoing assessment made by the IPCC.

The disproportionate impacts of extreme climatic events on terrestrial ecosystems, their huge consequences on societal and economic well-being, the evidence from observations that there has already been a change in the occurrence and frequency of some extremes and the projected increases in intensity and/or frequency of environmental extremes - these are all reasons for concern.

CARBO-Extreme´s objective was to obtain a better and more predictive understanding of European terrestrial carbon cycle responses to climate variability and extreme weather events. The consortium has combined a great variety of observations of ecosystem responses to climate extremes with process-based numerical modelling in a new model-data integration framework to improve our diagnostic and prognostic understanding of climate-carbon interactions on time-scales from days to decades. By building a consistent harmonized multi-source database of European carbon cycle components for studying climate variability and extreme events and performing a Bayesian model calibration and comparison, we have been able to significantly improve terrestrial carbon cycle predictions and the assessment of their uncertainties in scenario analyses, and to provide support to EU and international climate and soil protection policies.

CARBO-Extreme Work Structure



CARBO-Extreme consists of three components:

- **Observation component**
- process studies on soil carbon vulnerability
- network of ecosystem manipulation experiments
- long-term observation data sets
- **Modelling component**
- model development & model-data integration
- model experiments & scenario analysis
- **Assessment component**
- carbon vulnerability synthesis
- dissemination and policy interaction

Work performed since the beginning of the project and the main results achieved so far.

In the following we highlight some of the work performed in the third reporting period. Scientific publications published in the context of CARBO-Extreme within the 3rd reporting period are shown, and some key results and activities are highlighted:
(*work performed and main results for the overall project duration are presented in the Publishable Summary Report of the Final Reporting*)

Scientific publications published by CARBO-Extreme researchers within the 3rd reporting:

Babst F., Carrer M., Poulter B., Urbinati C., Neuwirth B. and Frank D. (2012) 500 years of regional forest growth variability and links to climatic extreme events in Europe. Environ. Res. Lett. 7 doi:10.1088/1748-9326/7/4/045705

Babst F., Poulter B., Trouet V., Tan K., Neuwirth B., Wilson R., Carrer M., Grabner M., Tegel W., Levanic T., Panayotov M., Urbinati C., Bouriaud O., Ciais P. and Frank D. (2012) Site- and species-specific responses of forest growth to climate across the European continent. Global Ecology and Biogeography DOI: 10.1111/geb.12023

Barr A.G., Richardson A.D., Hollinger D.Y., Papale D, Arain M.A., Black T.A., Bohrer G., Dragoni D., Fischer M.L., Gu L., Law B.E., Margolis H.A., McCaughey J.H., Munger J.W., Oechel L W., Schaeffer K. (2013). Use of change-point detection for friction–velocity threshold evaluation in eddy-covariance studies. AGRICULTURAL AND FOREST METEOROLOGY, vol. 171-172, p. 31-45

Chen, T., G.R. van der Werf, R.A.M. de Jeu, G. Wang, and A.J. Dolman (2013) A global analysis of the impact of drought on net primary productivity, Hydrol. Earth Syst. Sci. Discuss., 10, 2429-2451, doi:10.5194/hessd-10-2429-2013

De Simon G., Alberti G., Delle Vedove G., Peressotti A., Zaldei A., and Miglietta F. (2013) Short-term cropland responses to temperature extreme events during late winter. Biogeosciences Discuss., 10, 6493–6515, 2013. doi:10.5194/bgd-10-6493-2013

Epron D, Bahn M, Derrien D, Lattanzi F, Pumpanen J, Gessler A, Hogberg A, Dannoura M, Gerant D, Maillard P, Buchmann N (2012) Pulse-labelling trees to study carbon allocation dynamics: a review of methods, current knowledge and future prospects. Tree Physiology (Tree Physiology 00, 1–23), 10.1093/treephys/tps057

Forkel M., Carvalhais N., Verbesselt J., Mahecha M.D., Neigh C.S.R. and Reichstein M. (2013) Trend Change Detection in NDVI Time Series: Effects of Inter-Annual Variability and Methodology. Remote Sens. 2013, 5, 2113-2144; doi:10.3390/rs5052113

Maire Vincent, Alvarez Gaël, Colombet Jonathan, Comby Aurélie, Despinasse Romain, Dubreucq Eric, Joly Muriel, Lehours Anne-Catherine, Perrier Véronique, Shahzad Tanvir and Fontaine Sébastien (2012) An unknown respiration pathway substantially contributes to soil CO2 emissions. Biogeosciences Discuss., 9, 8663–8691, www.biogeosciences-discuss.net/9/8663/2012/; doi:10.5194/bgd-9-8663-2012

Martin–StPaul N.K., Limousin J.M., Vogt-Schilb H, Rodríguez-Calcerrada J, Rambal S, Longepierre D and Misson L (2013) The temporal response to drought in a Mediterranean evergreen tree: comparing a regional precipitation gradient and a throughfall exclusion experiment Global Change Biology. DOI: 10.1111/gcb.12215

Meersmans, J., Martin, M. P., Lacarce, E., Orton, T. G., De Baets, S., Gourrat, M., Saby, N. P. A., Wetterlind, J, Bispo, A., Quine, T. A. and Arrouays, D. 2013. Estimation of soil carbon input in France: An inverse modelling approach. Pedosphere. 23(4): 422-436

Pérez-Ramos, Ignacio M., Rodríguez-Calcerrada Jesús, Ourcival Jean M. and Rambal Serge (2013) Quercus ilex recruitment in a drier world: A multi-stage demographic approach. Perspect. Plant Ecol. Evol. Syst. (2013), http://dx.doi.org/10.1016/j.ppees.2012.12.005

Rey, A., G. Etiope, L. Belelli-Marchesini, D. Papale, and R. Valentini (2012), Geologic carbon sources may confound ecosystem carbon balance estimates: Evidence from a semiarid steppe in the southeast of Spain, J. Geophys. Res., 117, G03034, doi:10.1029/2012JG001991

Ruiz-Benito P, Lines ER, Gomez-Aparicio L, Zavala MA, Coomes DA (2013) Patterns and Drivers of Tree Mortality in Iberian Forests: Climatic Effects Are Modified by Competition. PLoS ONE 8(2): e56843. doi:10.1371/journal.pone.0056843

Seeber J., Rief A., Richter A., Traugott M. & Bahn M. (2012): Drought-induced reduction in uptake of recently photosynthesized carbon by springtails and mites in alpine grassland. Soil Biology and Biochemistry 55, 37-39. Doi: 10.1016/j.soilbio.2012.06.009

van Oijen M., Reyer C., Bohn F.J., Cameron D.R., Deckmyn G., Flechsig M., Härkönen S., Hartig F., Huth A., Kiviste A. , Lasch P., Mäkelä A., Mette T., Minunno F., Rammer W. (2013) Bayesian calibration, comparison and averaging of six forest models, using data from Scots pine stands across Europe. Forest Ecology and Management 289, 255–268. doi:10.1016/j.foreco.2012.09.043

van Oijen Marcel, Beer Christian, Cramer Wolfgang, Rammig Anja, Reichstein Markus, Rolinski Susanne and Soussana Jean-Francois (2013) A novel probabilistic risk analysis to determine the vulnerability of ecosystems to extreme climatic events. Environ. Res. Lett. 8 (2013) 015032. doi:10.1088/1748-9326/8/1/015032

Vicca, S., Gilgen, A. K., Camino Serrano, M., Dreesen, F. E., Dukes, J. S., Estiarte, M., Gray, S. B., Guidolotti, G., Hoeppner, S. S., Leakey, A. D. B., Ogaya, R., Ort, D. R., Ostrogovic, M. Z., Rambal, S., Sardans, J., Schmitt, M., Siebers, M., van der Linden, L., van Straaten, O. and Granier, A. (2012), Urgent need for a common metric to make precipitation manipulation experiments comparable. New Phytologist. doi: 10.1111/j.1469-8137.2012.04224.x

Wang, L., Ibrom, A., Korhonen, J. F. J., Arnoud Frumau, K. F., Wu, J., Pihlatie, M., and Schjoerring, J. K. (2012) Interactions between leaf nitrogen status and longevity in relation to N cycling in three contrasting European forest canopies. Biogeosciences Discuss., 9, 9759-9790, doi:10.5194/bgd-9-9759-2012, 2012.

Wu J., Jansson P.E., van der Linden L., Pilegaard K., Beier C., Ibrom A. (2013) Modelling the decadal trend of ecosystem carbon fluxes demonstrates the important role of functional changes in a temperate deciduous forest. Ecological Modelling 260 (2013) 50– 61. DOI 10.1016/j.ecolmodel.2013.03.015

Zscheischler, J., Mahecha, M.D., Harmeling, S. and Reichstein, M. (2013) Detection and attribution of large spatiotemporal extreme events in Earth observation data. Ecological Informatics, 15, 66-73.

Highlights of work performed by CARBO-Extreme researchers within the 3rd reporting:

A synthesis paper based on soil respiration measurements from 52 precipitation manipulation experiments revealed that structural and functional changes in the ecosystem profoundly alter the response of soil respiration to moisture (Vicca et al., in review).

Climate sensitivity and extreme growth anomalies across Europe during the past 500 years were catalogued based upon a dataset containing 992 sites and representing 36 different tree species across Europe. It could be shown that the occurrence of spatially extensive reductions in radial growth during certain years such as 1976 provides insights into terrestrial carbon uptake prior to periods covered by satellite, eddy-covariance, and even instrumental climate data. (Babst et al. (2012, 2013)

Forests at developing stages, due to legacy land use effects, may have the highest carbon sink potential under warming conditions, yet could be strongly constrained by concomitant decreasing water availability (see task 3.2 Final report)

A new technique for identification of extremes in anomalies of spatiotemporal long-term observations relevant to the terrestrial carbon-cycle variables was developed by Zscheischler et al. (2013). This analysis indicated that the global effect of climate extremes is of similar magnitude as the current terrestrial mean carbon sink. On-going work suggests that very few though large spatiotemporal extreme events may explain most of the inter-annual variability of land carbon fluxes

Model simulations over Europe identify the area around the Baltic Sea, Ukraine/Moldavia and Spain and France as region that require particular attention regarding their future carbon balance in relation to climate variability. Moreover, the models predict risks of carbon losses central Europe and the Mediterranean by droughts, while Northern Europe seems unaffected.

A comparison of the results of the dynamic vegetation model LPJmL simulated with control climate and climate with reduced variability (all other factors being equal), shows that climate variability accelerates fire along biome boundaries and the two factors together decrease tree abundance and productivity to an extent, where the treeline between steppe and temperate forests is likely to be shifted northwards (see task 6.2 Final report)

Vicca et al. (2012) discusses problems that arise when comparing precipitation manipulation experiments. The need for a reliable quantification of the actual manipulation is illustrated and the measurements to do are indicated with an example and contrasted with the data that are currently available.

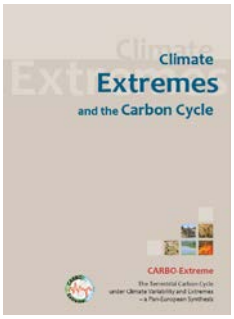
Description of the expected final results and their potential impacts and use

The final results for the overall project duration are presented in the Publishable Summary Report of the Final Reporting.

CARBO-Extreme results confirm that climate extremes strongly influence terrestrial ecosystems and their carbon cycle. Changing climate variability and an increasing number of weather extremes will increase the vulnerability of terrestrial carbon sinks. All land use types in Europe (largely comprising croplands, grasslands and forests) are vulnerable to climate extremes to some degree. Multiple evidence indicates that water-cycle extremes, in particular droughts, are a dominant threat to carbon cycle related ecosystem services. Climate variability will be most likely the factor, which will limit the capacity of the investigated ecosystem types to adapt to climate change. Taken together, with both their large carbon stocks and long generation time, forests are expected to experience the largest, most diverse, and longest lasting consequences for carbon cycling from climate extremes compared to other land-cover types, and the consequences of extreme events can largely offset the positive effects of carbon fertilization in an enriched CO_2 atmosphere.

The communication between CARBO-Extreme and European stakeholders and decision-makers initiated via a stakeholder dialog in April 2010, was strengthened via the Potsdam workshop (March 07/08 2013) where CARBO-Extreme had the chance to present and review its key project findings and questions with decision-makers/ knowledge brokers for Carbon Management.

The scientific knowledge obtained was communicated to scientists, policy-makers, stakeholders and decision makers through the compilation of the CARBO-Extreme brochure. The brochures are distributed amongst the CARBO-Extreme beneficiaries, associated site partners, the European Commission, stakeholders, as well as on scientific meetings. A web download will be implemented via the **Project web page http://www.carbo-extreme.eu/**.



Over 60 peer reviewed scientific publications related to CARBO-Extreme published until 31.May 2013 by CARBO-Extreme researchers made project results highly visible in the research community (see at Publications on http://www.carbo-extreme.eu).

The “Open Science Conference on Climate Extremes and the Biogeochemical Cycles” (see http://www.bgc-extremes2013.org), a joint initiative of CARBO-Extreme, the US-based network INTERFACE, and the international activity iLEAPS funded by the International Geosphere-Biosphere Program, with over 150 researchers from Europe, Asia and the US, contributed substantially to spread the knowledge about climate variability and the carbon cycle and CARBO-Extreme in the research community.

In different press media and via press releases information about climate extremes and CARBO-Extreme´s open science conference was reported in the third reporting period (links and downloads available via http://www.carbo-extreme.eu/index.php/Press/Press):

Nature News reported April 11th about CARBO-Extreme´s "Open Science Conference on Climate Extremes and the Biogeochemical Cycles" held April 2013 in Seefeld (Austria) (Nature Vol.496 p.147; doi:10.1038/496147a) contributing substantially to spread the knowledge about CARBO-Extreme´s activities in the research community.

A press releases "Heat waves, ice-storms, droughts and hurricanes –their impact on the carbon cycle" (see http://idw-online.de/en/news526117) was published the 03/28/2013 via idw scientific information service.

Results and work coming out of CARBO-Extreme has been presented by project participants in numerous national and international conferences and workshops related to the topics of climate change and extreme events, amongst others the EGU 2013 General Assembly Meetings in Vienna, the Open Science Conference on Climate Extremes and the Biogeochemical Cycles (Seefeld, April 2013) and the 9th International Carbon Dioxide Conference, Beijing, China (June 2013).

A Data Exchange Portal accessible via the CARBO-Extreme webpage www.carbo-extreme.eu has been established. It allows project related data **downloads** and **uploads** after registration. Whereas public files are **freely** available for everyone, other files are freely available for project members and available upon **request** for others.

A Special Issue of Biogeosciences on "Climate extremes and biogeochemical cycles in the terrestrial biosphere: impacts and feedbacks across scales" edited by CARBO-Extreme members is planned (see http://www.biogeosciences.net/submission/scheduled_special_issues.html#36).

Further future exploitation potential e.g. with regard of the developed concept of probabilistic vulnerability and risk indices or the identification of hotspots of climate vulnerability can be found with more detail in the Final Publishable Summary of CARBO-Extreme.

Peer reviewed scientific publications of project CARBO-Extreme

Babst F., Carrer M., Poulter B., Urbinati C., Neuwirth B. and Frank D. (2012) 500 years of regional forest growth variability and links to climatic extreme events in Europe. Environ. Res. Lett. 7 doi:10.1088/1748-9326/7/4/045705

Babst F., Poulter B., Trouet V., Tan K., Neuwirth B., Wilson R., Carrer M., Grabner M., Tegel W., Levanic T., Panayotov M., Urbinati C., Bouriaud O., Ciais P. and Frank D. (2012) Site- and species-specific responses of forest growth to climate across the European continent. Global Ecology and Biogeography DOI: 10.1111/geb.12023

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Beer, C., Reichstein, M., Tomelleri, E., Ciais, P., Jung, M., Carvalhais, N., Rodenbeck, C., Arain, M.A., Baldocchi, D., Bonan, G.B., Bondeau, A., Cescatti, A., Lasslop, G., Lindroth, A., Lomas, M., Luyssaert, S., Margolis, H., Oleson, K.W., Roupsard, O., Veenendaal, E., Viovy, N., Williams, C., Woodward, F.I. and Papale, D. (2010) Terrestrial Gross Carbon Dioxide Uptake: Global Distribution and Covariation with Climate. *Science*, 329, 834-838

Bellarby, J., Wattenbach, M., Tuck, G., Glendining, M.J. and Smith, P. (2010) The potential distribution of bioenergy crops in the UK under present and future climate. Biomass and Bioenergy 34 1935-1945.

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