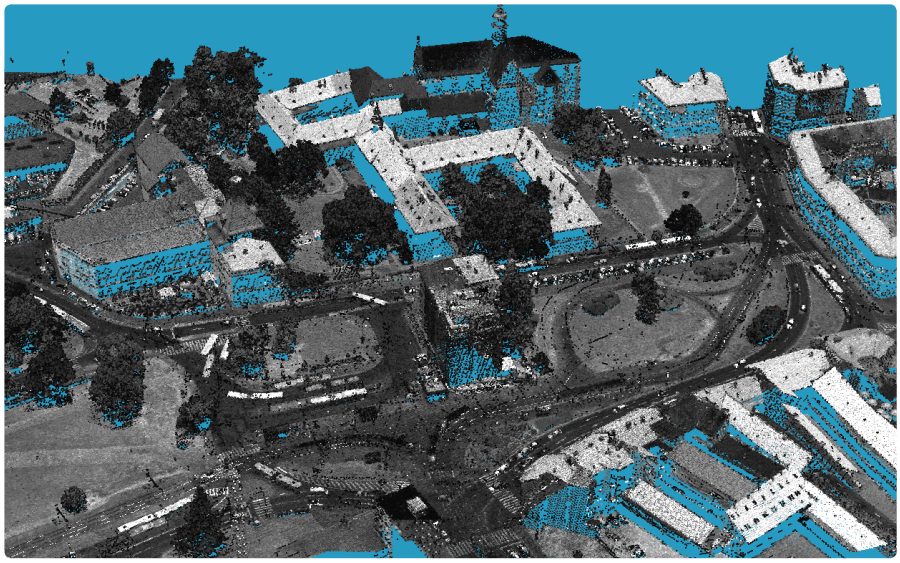
Newsletter

2/2016

CzechGlobe

Global Change Research Institute CAS

LIDAR WILL ENABLE IMAGING IN NEW DIMENSIONS



Lately, we have witnessed that for several months in a row temperatures measured on Earth were always higher than the temperatures in previous years. Extremely high temperatures persisting for several days and threatening the very essence of life were recorded in the Middle East. Also in the Czech Republic the forecasters had predicted even drier and hotter summer than in the previous year, but fortunately their prognosis did not come true. In the context of dramatic weather events in the world, at least the weather in the Czech Republic was in terms of temperature and precipitation, more or less average and did not yield any significant extreme episodes. Although this year was not as rainfall deficient as the previous one, when the total annual rainfall in the Czech Republic reached only 79% of long-term average, the state of groundwater in many places in the Czech Republic is alarming. The nightmare in the form of drought therefore remains a constant challenge. In fact, it is the long-term drought that is one of the priority themes of the approved Strategy for adaptation to climate change in the conditions of the Czech Republic (National Adaptation Strategy), whose aim is to mitigate the effects of climate change by adapting to the change as much as possible. National Adaptation Strategy defines the areas which are anticipated to suffer the greatest impacts of the climate change. They are mainly agriculture, forestry, water regime in the landscape and water management, biodiversity and ecosystem services and urbanized landscape. They are the fields where the scientists from CzechGlobe significantly contribute, both with their results as well as using their specialized activities, to the creation and implementation of the strategy in the long term. The achievements in recent years which were very significant in this respect include the organization of the conference called “How to prepare the Czech Republic for the climate change?” and the signing of the Memorandum on cooperation in monitoring agricultural drought with the State Land Office. Both of these events are covered in other parts of this newsletter.

To operate and provide an internationally important research infrastructure, which CzechGlobe has undoubtedly become, is a long-term job. We cannot be satisfied with the fact that we have built something, we need to constantly follow new trends and to upgrade and add to the existing infrastructure. At the same time research should be as comprehensive and effective as possible. That was why CzechGlobe decided to purchase the airborne laser scanner LiDAR for the Laboratory of remote sensing. This multimillion-dollar investment will complement existing hyperspectral sensors, whose data is widely used e.g. for applications in precision agriculture, where it is mainly about the monitoring of a deficiency of nutrients and soil moisture, for estimates of expected revenues or resources of biomass, further also in geology and soil science, and last but not least, for monitoring the quality of water in water bodies. LiDAR data will then be used to estimate the structural parameters of the given territory and will help create 3D models. Indisputable advantage of LiDAR are lower demands on atmospheric conditions during the imaging, which basically means that it is possible to image even when it is cloudy and not only on bright sunny days, which is required when using hyperspectral sensors.

The end of the year is a time for retrospection. In the last issue we addressed the evaluation of scientific teams, so in this issue let’s evaluate the grant success rate. The recently published results of the Czech Science Foundation showed that we achieved 30% success rate in terms of standard projects, and out of three junior grants, two were successful. Within the TA CR Epsilon Programme supporting applied research, we succeeded with two of our projects. Other results of the national R&D tenders, for instance the INTEREXCELLENCE programme, are not yet known, but we are pleased that we succeeded in the HORIZON 2020 programme five times in 2016.

What to wish in the end? - a peaceful Christmas and the entire upcoming year and perhaps once more the proper “Lada’s winter” with an abundant snow cover. It is something that Nature, and perhaps some of us as well, need so badly. -mš-

WE ARE INTRODUCING THE LABORATORY OF METABOLOMICS AND ISOTOPE ANALYSES

OUR ROLE IN CZECHGLOBE IS TO CONVEY THE USE OF THE LATEST FINDINGS IN THE FIELD OF ENVIRONMENTAL CHEMISTRY TO OUR COLLEAGUES,

says prof. Ing. Jan Tříska, CSc., the head of the Laboratory of metabolomics and isotope analyses. Prof. Tříska graduated from the Faculty of Fuel and Water Technology at the University of Chemistry and Technology in Prague, where he also habilitated. He was appointed Professor of Environmental Chemistry at Masaryk University in Brno. Since the 80's he lectured at the University of Chemistry and Technology in Prague, later on at the Faculty of Biology (later Faculty of Science) of the University of South Bohemia, where he acted as the guarantor of specialized courses in the field of environmental chemistry. He participated in the establishment of a common field of study called Environmental chemistry for the students of the Johannes Kepler University in Linz. He also acts as a member of departmental boards, he is a founding member of the Engineering Academy of the Czech Republic and a member of the Main board of the Czech Chemical Society. He has worked at a number of foreign institutions.

First of all, I must ask, "what is metabolomics"?
Metabolomics is a very interesting and relatively new scientific discipline focused on the description, identification and quantification of metabolites, which are products of metabolism. Metabolites are low molecular weight compounds, and the entire collection of them in a given biological system, which may be a cell, tissue or organism, is called metabolome. Hence the term metabolomics, which was postulated at the turn of the millennium by prof. Fiehn.
Metabolites of a single organism are usually very different types of substances. If we compare them e.g. with proteins and peptides, which are based on amino acid sequence and which are certain macromolecules, metabolites belong to different groups of different chemicals. This makes it more difficult to determine them, because we have to use different techniques. In contrast to genomics, proteomics, transcriptomics, which use a small number of standard techniques, such as capillary electrophoresis, with metabolomics we have to use a number of sophisticated devices, since there is a wide range of chemical structures. They may be various sugars, lipids, amino acids and other substances that have chemically very little in common. Essentially, the only thing that connects them is that they are organic molecules of relatively low molecular weight (up to approx. 1 kDa).

How is metabolomics related to global change and to the focus of the institution in general?
Metabolomics, unlike the aforementioned „omics", reflects more the current state of the cell, which is highly dynamic. The level and number of metabolites is not only the result of gene expression and related enzymatic pathway, but also the influence of environmental conditions which it is in. Accordingly we use the term environmental metabolomics, and it is directly related to the issues of global change.
We focus on the plants, and it is apparent that the plant cells will respond to changing external conditions associated with the global change. It may be a change in the concentration of carbon dioxide, changes in UV radiation, changes in the temperature and humidity conditions, or secondarily induced reactions, e.g. infestation by pathogenic organisms and mycotoxins production, or affected metabolism by the influence of invasive plants. Generally, it is therefore a stress response which is immediately reflected in the metabolomic profile of a given biological system. These are the points of our research where we primarily intersect with the activities of the Laboratory of ecological plant physiology led by assoc. prof. Urban. One of the effects we are currently monitoring is the effect of nanoparticles of cadmium oxide on barley plants.
It was just when the CzechGlobe project was starting to shape, that prof. Marek approached our group of analytical chemists in the former ISBE with an offer of whether we are interested in participating in the creation of a conceptually new institution and in building a metabolomic laboratory. Of course, we were excited. We felt that this way, such very different analytical techniques, which form a metabolomic platform, will systemically interconnect within a single institution. This vision proved to be viable and what's more it was obvious that the proposed idea of the Centre is really targeted to ensure conditions for long-term cooperation between disciplines.

You mentioned that metabolomics is a new discipline. How did it develop?
Existing platforms using GC-MS and LC-MS techniques (gas and liquid chromatography with mass spectroscopy) require at least partial breakdown of metabolites. I believe that in the near future it will be possible to analyze the metabolites directly within the cell, without extraction, by introducing the cells into the mass spectrometer.
Aside metabolomic approaches not requiring the breakdown of analytes, e.g. the actual mass spectrometry and primarily NMR spectroscopy, the development of metabolomics was largely dependent on the development of chromatographic methods. In the sixties of the last century, the Czechoslovak chromatographic school was highly recognized in the world. Its representatives were, for example, prof. Janák, prof. Churáček, assoc. prof. Macek and other researchers. The key moment was the development of fused silica capillary columns. In the USA the silica capillary column was patented in 1979, in Czechoslovakia two years later. I am very glad that I could be a member of the team that developed these capillaries. Concurrently, the development in the field of liquid chromatography and mass spectrometry took place. Of course we cannot ignore the development in computer technology and software, without which metabolomics could not have developed.
It also must be said that metabolomic experiments generate large amounts of data that must be efficiently processed, interpreted and archived. This part is usually, besides the sample preparation, key and needs to be paid close attention to. For process analyses there are various software tools, which are usually very expensive. Raw data is mostly in the form of the chromatogram, where beside the retention data, there is another dimension of spectral data, and all this is multiplied by the number of respective measurements. In the end, the resulting matrix for statistical processing is enormous.

You have used the term "metabolomic platform" several times. Can you explain it?
The summary of procedures starting by quenching metabolism (e.g. in liquid nitrogen), continuing with the extraction of metabolites, their purification and concentration through different techniques, their derivatization and the analysis itself using GC-MS, or more precisely LC-MS, using different methods of ionization is called the metabolomic platform and it is a specific feature and know-how of each laboratory, even though these procedures are generally described in literature. With every extension of a metabolomic platform, we get a

different, unique view of the final composition of the metabolome. In our laboratory, we have several platforms, but our short-term aim is to expand metabolomic platform by introducing the analysis of optically active substances, and the inclusion of the analysis of stable isotopes.

You've already mentioned the cooperation within CzechGlobe. What other institutes do you work with?

I would like to point out that thanks to the knowledge and experience we have gained as analytical chemists, we don't only see metabolomic outcomes. However, in some of the metabolites we also see chemicals with significant biological effects and we further deal with them. I would like to mention two examples. Within CzechGlobe the most studied tree species is Norway spruce, based on which a number of scientific works have been published. In terms of Norway spruce, we focused primarily on lignans in knots, where there is a large amount of hydroxymatairesinol (HMR), a major lignan with significant chemopreventive effects against cancer. Currently, the project NAZV is about to be completed, in which, in cooperation with the Food Research Institute Prague, we prepared and patented a wide range of dietary supplements containing the mentioned HMR. Another important cooperation concerns the Faculty of Horticulture in Lednice and its two departments, with which we are currently addressing the task regarding processing of biologically active substances (viniferins) from grapevines and their use in food supplements. Resveratrol and its oligomers from vines serve as substances of significant biological effects, e.g. in the world they are tested as agents against Alzheimer's disease, and as well as agents of fungicidal properties. For the development of fungicides from vines, we gained a TA CR project.

One of our activities covers chemical substances in the components of the environment. According to the data from 2014, in the components of the environment there are approximately 90 million chemical compounds, of which only about 0.3% is tested for biological effects. It is therefore only the proverbial tip of the iceberg. In addition to that, there are approximately another 15,000 new chemicals getting into the environment every day. We focused on steroid substances and medicaments in the aquatic ecosystem, because some of them are biologically active even at very low concentrations of about 1 ng/l of water. In this area, we have been closely cooperating with the USGS in Denver and solving the issue of the effectiveness of root wastewater treatment plants. We are solving the issue of pharmaceuticals in the aquatic ecosystem, their transfer to plants and their effect on the metabolism of selected plants together with the Faculty of Science, Masaryk University in Brno, and we have also filed a joint project with the Johannes Kepler University in Linz.

I would also like to mention the key international cooperation, especially important in the early days of building the Laboratory of metabolomics. Without them it would have been very hard to develop the laboratory properly. First and actually the nearest department was the Department of Molecular Systems Biology at the University of Vienna, where prof. Weckwerth works. Another international cooperation between CzechGlobe and CREAF-University of Barcelona (prof. Peñuelas) is still supported by intensive exchange of staff. As for the broader issue of plant hormones we cooperate with prof. Roitsch from the University of Copenhagen.

Given the fact that we are able to determine precise molecular weight, we are approached by the departments dealing with the synthesis of organic substances, especially pharmaceuticals. E.g. we assess the structure of the medications being developed for the Faculty of Pharmacy at the University of Veterinary and Pharmaceutical Sciences Brno. We have a long-term and successful cooperation with the Institute of Chemical Processes in Prague and the University of Chemistry and Technology Prague. Together with the Institute of Chemical Processes, we have developed a vibratory extraction column used for the extraction of phytosterols from waste material of paper industry. This column is patented. We also have long-term cooperation with the Faculty of Agriculture at the University of South Bohemia in České Budějovice. Testing the biological efficiency of prepared chemicals is carried out in collaboration with the Faculty of Science, University of South Bohemia in České Budějovice. Currently we are testing antiviral effects of selected chemical substances.

LABORATORY OF METABOLOMICS AND ISOTOPE ANALYSES

At the GCRI, the Laboratory of metabolomics and isotope analyses falls within the Domain of environmental effects on terrestrial ecosystems. The Laboratory deals with the study of biochemical profile of selected substances - metabolome and biologically active substances affected by biotic and abiotic stress in response to global changes.

Currently, six scientists and two laboratorians work at the Laboratory.

CONFERENCE "HOW TO PREPARE THE CZECH REPUBLIC FOR CLIMATE CHANGE?"

On 10th November 2016, GCRI held, together with Mendel University, within the scope of the CzechAdapt project a discussion conference called "How to prepare the Czech Republic for climate change?". Presented academic papers were devoted to climate change and its expected impacts, to the adaptation measures for the global agricultural economy, food security and the adaptation to climate change from a European perspective. All the conference participants from the ranks of scientists, state administration staff and public sector had the opportunity to express their views on the issues presented through an active poll. The poll showed that among the participants there was a consensus, e.g. that the drought and other hydrometeorological symptoms are the most significant manifestations of the climate change, that reducing emissions is the most important mitigation measure and that the adaptation in the agricultural sector should be one of the priorities for the national economy of the Czech Republic. The poll results will serve the scientists as a basis for further scientific processing.

WARMING WILL PROCEED MORE QUICKLY

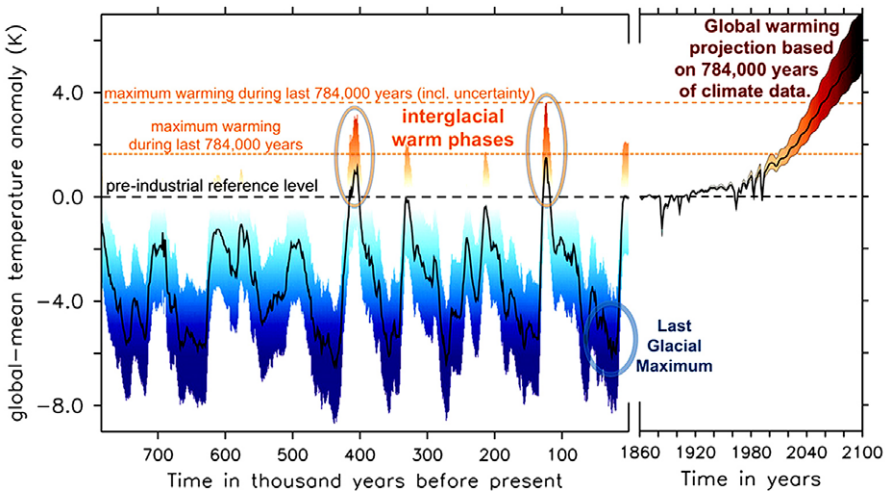
GOT OUR ATTENTION

There is no doubt that the continuing growth in concentrations of greenhouse gases (GG) will cause that the Earth will continue to warm up. However, there is uncertainty about the extent of warming for a given concentration of GG. The current scientific consensus says that if the concentration of carbon dioxide (CO_2) doubles from a pre-industrial value of 280 ppm (parts per million, i.e. 0.028%) to 560 ppm, the temperature will increase by about 3°C. The uncertainty in this estimate is caused primarily due to hardly predictable feed-back mechanisms, such as changing the albedo of the Earth's surface, changing the water vapor content, or change in the amount and type of cloudiness.

There are several ways of how to estimate climate sensitivity to changes in CO_2. The most direct way is to estimate the energy balance of the atmosphere using the measured temperatures for about the last 130 years. Based on these studies, the latest report of the IPCC panel (Intergovernmental Panel on Climate Change) has reduced the lower limit of climate sensitivity down to 1.5°C compared to the previous 2°C. However, after the inclusion of data from the Arctic, which is warming the fastest, it shows that this estimate is too low. This is also indicated by estimates of climate sensitivity using another method, a method of climate models. They indicate the mean estimate for warming after CO_2 has doubled of approximately 3°C. The third option is to compare the development of climate change with changes of CO_2 in the distant past of the planet.

A new piece of work by Friedrich et al. published in the Science Advances journal used the third option. In their work, the authors presented a new record of air temperature for almost the last 800 thousand years, derived from data taken from marine sediments and air bubbles in glaciers. Their calculation of climate sensitivity included information on changes in CO_2 concentration and astronomical "Milankovitch" factors affecting the radiation balance of the atmosphere. According to the results thus obtained, the climate sensitivity is as high as 4.9°C. If these results turn out to be correct, it means that to avoid reaching a certain threshold of warming, we have about 10 to 15 years less time than previously thought. According to the authors of the study, it is still theoretically possible that the world manages to avoid a long term warming of more than 2°C, i.e. over the threshold which is still considered safe. The chances are, however, still smaller and smaller. The results of this study showing greater climate sensitivity to changes in the CO_2 concentration in the atmosphere are consistent with a study analyzing the PETM period (Paleocene–Eocene Thermal Maximum) 55 million years ago, according to which the climate sensitivity increases with warming. It seems that it is in virtue of the activated enhancing feed-back mechanisms that do not manifest in cold climates. **-aa-**

Quotation: Friedrich T., Timmermann A., Tigchelaar M., Timm O.E., Gonopolski A.: Nonlinear climate sensitivity and its implications for future greenhouse warming, Sci. Adv. ;2: e1501923 (2016).



Change in global temperature over nearly the last 800,000, with an outlook up to the year 2100. If greenhouse gas emissions are not reduced, global temperature exceeds the natural variability for over the last 800,000 years at the beginning of the second half of this century. The temperature increase is more dramatic than the latest report of the IPCC panel expected. Source: http://advances.sciencemag.org/content/2/11/e1501923

WHAT´S NEW

Memorandum on cooperation in monitoring agricultural drought

On 5th October 2016 in Pilsen, on the eve of the conference „Landscaping - a tool for the adaptation to changing climate," the director of CzechGlobe, prof. Michal V. Marek, and the General Director of the State Land Office, Ing. Svatava Maradová, signed a Memorandum on cooperation in monitoring agricultural drought, its further development and possible use.

Conference Urban adaptation, planning and practice: Supporting nature-based solutions

From 17th to 19th October 2016, GCRI held an international conference called „Urban adaptation, planning and practice: Supporting nature-based solutions" at the premises of the New Town Hall in Prague.

The conference, which was one of the outputs of the UrbanAdapt project, not only aimed to share experience and introduce the examples of good practice in the field of planning and development of adaptations and ecosystem-based approaches across European cities, but also to support the development and implementations in cities.

Science and Technology Week

1st November – 13th November 2016. Also this year we participated in the largest science festival in the Czech Republic called the "Science and Technology Week CAS". This year, already the sixteenth, was in the spirit of the motto "Beyond the known". CzechGlobe presented itself during the three-day-long exhibition at the Academy of Sciences in Prague with its exposition called "On climate in a different way". The exposition introduced the visitors to the methods of historical climatology, to the use of thermal cameras in the identification of plant responses to drought and to the use of hemispherical photographs for the research in the processes of forest ecosystem. Within the STW we also prepared a series of eight popular science lectures, which were presented to general public directly at the GCRI Brno, at the Observatory and the Literary Café.

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