Summary article for customer newsletter:

CPEC310 and AP200 Key to Studies in China Forest Laboratories

Campbell Scientific scientists in Utah and in Beijing are making great strides in research in the forests of Northeast China. Working together with the Institute of Applied Ecology, the Chinese Academy of Sciences (CAS), they formed the Ker Joint Laboratory (CAS-CSI Joint Laboratory of Research and Development for Monitoring Forest Fluxes of Trace Gases and Isotope Elements).

The objectives of this joint operation include flux measurement and related studies over a varied forest landscape. The team designed a state-of-the-art system consisting of three towers in different types of forest to make the necessary measurements, and the CPEC310 and AP200 are at the heart of each tower station.

The team hopes to overcome the difficulties of obtaining comparable data from the diverse conditions, and further the state of flux science in this area.
(Full report available here.)

Full text to place in technical paper section of website:

Integration of CPEC310 and AP200 Systems to Explore the Theories and Techniques of Measuring the Fluxes of CO2/H2O/Trace-Gases over Heterogeneous Landscapes in Chinese Academy of Sciences Qingyuan Forest CERN Laboratory

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CPEC310 (closed-path eddy-covariance systems) and AP200 (atmospheric profile systems), along with micrometeorological sensors, nitrate-related trace-gas analyzers, and soil-surface CO_2 flux systems, have been integrated into three 50-meter-tall towers facilitating studies on forest ecology and management in the Chinese Academy of Sciences Qingyuan Forest CERN (China Ecology Research Network) Field Laboratory (Fig. 1). Taking advantage of new developments in the CPEC and AP systems from Campbell Scientific, the integrated network of systems is a state-of-the-art design to explore the theories and techniques of measuring the fluxes of CO_2/H_2O/trace-gases over mountain forests (i.e., heterogeneous landscapes). It does this while collecting long-term data of the fluxes over Qingyuan Forest CERN watershed covered with the three types of forests (natural mixed broadleaf deciduous forest, natural Mongolian oak forest, and larch plantation forest) that are most common in Northeast China.

Fig. 1. The three towers facilitating studies on forest ecology and management over the watershed of Qingyuan Forest CERN (China Ecology Research Network, Chinese Academy of Sciences) are located inside three forest sites categorized as natural mixed broadleaf deciduous forest (the left nearest tower), natural Mongolian oak forest (the right tower), and planted larch forest (the farthest tower). The three forests represent the three major types of secondary forest ecosystems in Northeast China.

Qingyuan Forest CERN CAS

Qingyuan Forest CERN is a field laboratory directly supported in a long-term by the Chinese Academy of Sciences (CAS) and is administrated principally by the Institute of Applied Ecology (IAE), CAS. It is open internationally for collaborations among ecologists, meteorologists, and hydrologists on forestry. Dr. Jiaojun Zhu is the director of Qingyuan Forest CERN, while also being the director general of IAE, CAS. Having his philosophy of research in field forests representative to most cases (e.g. mountain forests over heterogeneous landscapes, Fig. 1), he chose a mountain watershed covered with natural mixed broadleaf, natural oak, and planted larch forests as a practical field of Qingyuan Forest CERN. In 2003, he designed and established this field laboratory to be comprehensive enough for major projects in forest ecology and management, as well as the resulting environmental influences. These projects are funded by China National Science Foundation, CAS, and the China Council of Sciences and Technology. Now, the dozens of projects with annual support of millions in US dollars are running here. Apparently, long-term quality data to quantify the exchange of CO_2/H_2O and nitrogen-related trace gases between forest ecosystems and the atmosphere (i.e., fluxes over forests) as influenced by forest growth and development under human disturbance are indispensable in this laboratory (Zhu et al., 2018).

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Integration of CPEC310 and AP200 systems with other sensors

The field of mountain forests in Qingyuan Forest CERN over a heterogamous landscape theoretically challenges the techniques of measuring fluxes that are commonly applicable to homogenous landscapes. Requiring data to be as continuous as possible in time series with quality, the major objective of Qingyuan Forest CERN instrumentally challenges the flux measurement equipment systems in their quality and functionalities as well. For the three towers, both challenges led to a choice of integration of the CPEC310 and the AP200 as state-of-the-art, major components. Also chosen were research-grade micrometeorological sensors, nitrate-related trace-gas analyzers durable in various weather conditions, and soil-surface CO_2 flux systems compatible with CPEC310 and AP200 in system control and data sharing.

CPEC310

CPEC310 is a newly released CPEC system (Fig. 2a and 2c) from Campbell Scientific. Its CO_2/H_2O flux measurements are the benchmark used to assess the same

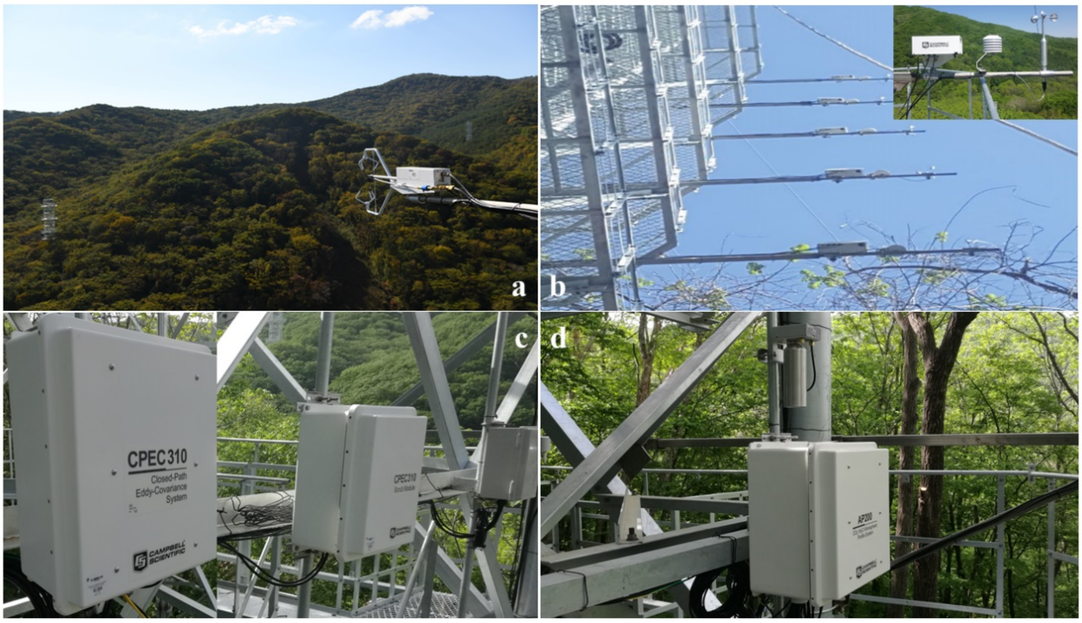

Fig. 2. The CPEC 310 (a and c) and AP200 (b and d) installed on a tower facilitating the studies on forest ecology and management over the watershed of Qingyuan Forest CERN (China Ecology Research Network, Chinese Academy of Sciences).

measurements by an open-path eddy-covariance (OPEC) system (Helbig et al. 2016). Compared with other CPEC systems, it has the fast response of 4.2 Hz cutoff frequency (Ma et al. 2017), less consumption of power, and consistent performance in various weather conditions (Novick et al. 2013). Compared to its OPEC counterpart, it measures the temperature and pressure of measured air flows more accurately in better synchronization by thermo-equilibrium design. This avoids the measurement errors incurred in an OPEC system in which pressure is assumed to be static for WPL correction (Webb et al 1980, Zhang et al. 2011), and the temperature for the correction of the spectroscopic effect on CO_2/H_2O signals at high frequency (e.g., 10 Hz) is measured using a conventional, slower sensor (e.g., a 107-probe. Wang et al. 2016b).

More importantly, the CPEC310 has two distinguishing advantages:

1. Functionality of auto-zero/span set at a user-defined hour interval. This functionality regularly (via user settings) adjusts the zero and span parameters in the working equation of a CO_2/H_2O analyzer (LI-COR Biosciences 2016) to fit the temperature near which the system is running, which technically improves the accuracies of measurements for CO_2/H_2O fluxes.
2. EasyFlux-DL-CR6CP software. This software controls and operates the measurements and auto-zero/span while processing the data as to the specifications the flux community has adopted.

AP200

The AP200, manufactured by Campbell Scientific, (Fig. 2b and 2d) is the atmospheric profile system to measure CO_2/H_2O, air temperature, and relative humidity at up to eight height levels, with their vertical distribution arranged by users. It is commonly used in connection with an eddy-covariance system. In this case, it was integrated with the CPEC310. Over an averaging interval used in CPEC310 for flux computation, its data from different levels are used to calculate the individual change in CO_2/H_2O and heat storages between biosphere and atmosphere over the profile up to the CPEC310 level (i.e., control volume). The changes are the increases/decreases in the storage inside the control volume, as such, being termed as storage terms. The amount of these terms depends on the interactions of boundary-layer stratifications with species composition, vegetative surface and volume densities, and their spatial distributions inside the canopy. In flux computation, therefore, the integration of these storage terms based on fast response profile system with fluxes measured by CPEC310 can greatly improve the reliability in an estimation of flux and even net ecosystem exchange (NEE, Wang et al 2016a), which has been advocated recently by the International Carbon Observatory System to standardize the methodology for the storage term measurements to the system infrastructure (Montagnani et al. 2018).

Similar to the CPEC310, the AP200 also has two distinguishing advantages: (1) Functionality of auto-zero/span, and (2) EasyFlux-DL-CR1KXAP software (under development). The software is adaptable, and for this case study it was modified to accommodate a vertical profile of cup anemometers (model: 010C, Met One Instrument, OR) and soil moisture and temperature measurements (models: CS655, TCAV, Campbell Scientific, UT). These additions enable the AP200 to measure more variables of interest for comprehensive analyses.

Micrometeorology sensors

For each tower: a CNR4 four-component radiometer (Kipp & Zonen, Amsterdam) measures incoming and outgoing radiation (longwave and shortwave) over forest canopy (Fig. 3a); three replications of HFP01SC self-calibrated soil heat-flux plates (Hukseflux Thermal Sensors, Delft), TCAV, and CS655 measure soil heat flux along with soil moisture and temperature profiles (Fig. 3b for one replication); SI-111 infrared radiometers measure surface temperature inside (Fig. 3d1) and outside canopy (Fig. 3d2); and a 5220 rain gage (R. M. Young Company, MI) measures precipitation (Fig. 3c).

Fig. 3 Micrometeorology sensors: (a) CNR4 four-component radiometer with CNF4 ventilation and heating accessories, (b) sensor assembly for soil heat flux along with soil moisture and temperature profiles, (c) 5220 rain gage, and SI-111 infrared radiometer outside (d1) and inside (d2) forest

Soil CO_2 flux system and trace-gas flux system

For each tower: a soil-surface CO_2 flux system compatible with CPEC310 and AP200 in system control and data sharing has been designed for CO_2 efflux from forest floor, and trace-gas analysis (TGA) (Campbell Scientific, UT) has been scheduled for the fluxes of nitrogen-related trace-gases. The trace-gas flux will be used to address the nutrient cycles in the three forest types and environmental interactions between agricultural and forest ecosystems.

Full options, research grade, and integration

Full options, when available, were chosen for any system installed in the three towers. CPEC310 has its options of valve and scrub modules for its best performance in auto-zero/span; AP200 has its option of a zero gas bottle along with the maximum number of sampling intakes for its most reliable measurements; CNR4 has its option of CNF4 to acquire better data in evening, low wind, and moist conditions; and 5220 rain gage has its option of a heating accessory for data availability in the winter season.

All sensors installed in the three towers are research grade for ecology. CNR4 is a high-end, four-component radiometer; HFP01SC is the only soil heat flux plate with self-calibration capability for forests; and 5220 rain gauge is a top-quality choice for attaching to the towers.

All the measurement systems and sensors are integrated into a whole system. The data from the CPEC310 are designed to be shared online by the AP200, the soil-surface CO_2 flux system, and the trace-gas system, and eventually to compute the values of variables at an ecosystem level (e.g., NEE). This computation can be summarized by the CR1000X Datalogger in the AP200. The summary can be a core data file robust enough for the use of most research topics on forest ecology and management.

Challenge, advantage, and perspective

For flux measurements and related studies, the field of mountain forests in Qingyuan Forest CERN over a heterogamous landscape is challenging, and the state-of-the-art design in an integration of CPEC310 and AP200 along with other quality sensors is an advantage. Facing the challenge and taking this advantage, the CAS-CSI Joint Laboratory of Research and Development for Monitoring Forest Fluxes of Trace Gases and Isotope Elements (Ker Joint Laboratory) (Fig. 4) has been established. This laboratory organizes scientists from the Institute of Applied Ecology, other institutes under CAS, Campbell Scientific, Campbell Scientific (Beijing) Company Limited, Shenyang Agricultural University, Northeast Forestry University, Beijing Techno Solutions Limited, and foreign visiting scientists as a team (Fig. 4b).

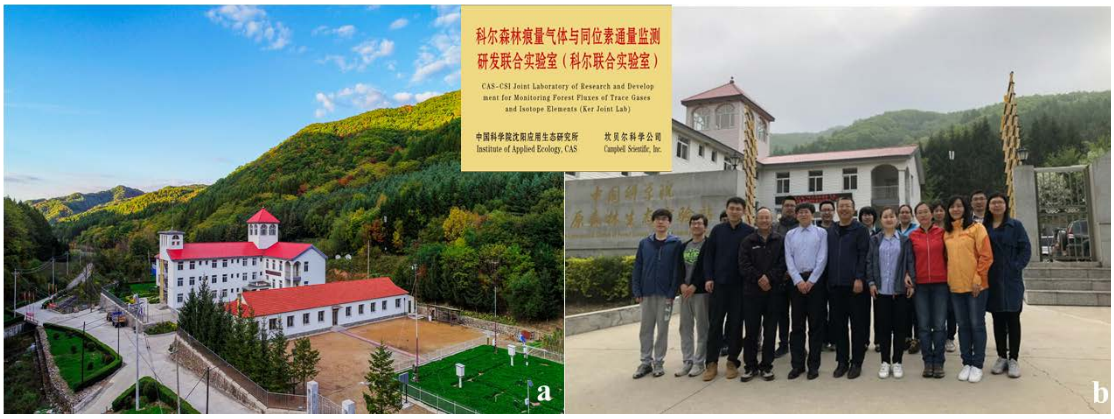

Fig. 4. CSA-CSI joint Laboratory of Research and Development for Monitoring Forest Fluxes of Trace Gases and Isotope Elements (a) and some team members (b)

While collecting long-term data, this team mainly focuses on the three tasks: (1) development of theories and techniques to measure the fluxes of CO_2/H_2O and nitrogen-related gases over mountain forests of the three types; (2) research education for master and Ph.D. candidates and postdoctoral fellows as well; and (3) applications of new developments in CO_2/H_2O and trace-gas flux systems from Campbell Scientific.

The team would project three perspectives: (1) Provide long-term data concerning fluxes and the environment as influenced separately by the three types of forests at an ecosystem scale, supporting all research projects conducted in the Qingyuan Forest CERN; (2) improve theories and techniques to measure fluxes of atmospheric constituents over heterogeneous landscapes; and (3) demonstrate the integration of the CPEC310 and AP200 to the China flux community as the best choice for future CERN updates of flux measurement systems.

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