

## CASE STUDY

# China: Flux Cooperation

### SUMMARY

This case study discusses the integration of CPEC310 and AP200 systems to explore the theories and techniques of measuring CO<sub>2</sub>/H<sub>2</sub>O/trace-gas fluxes over heterogeneous landscapes in the Chinese Academy of Sciences Qingyuan Forest CERN laboratory.

**Location:**

Northeast China

**Customer:**

Qingyuan Forest CERN, Chinese Academy of Sciences, Ker Joint Laboratory

**Products:**

CPEC310, CS655, AP200, CNR4-L, 52202-L, SI-111, TCAV-L, HFP01SC-L

**Measured Parameters:**

Fluxes of CO<sub>2</sub>, H<sub>2</sub>O, nitrate-related trace gases; profiles of air temperature, air moisture, soil temperature; CO<sub>2</sub> and H<sub>2</sub>O storage terms; energy terms; net ecosystem exchange



## INTEGRATING CPEC310 AND AP200 SYSTEMS TO EXPLORE THE THEORIES AND TECHNIQUES OF MEASURING FLUXES

CPEC310 (closed-path eddy-covariance systems) and AP200 (atmospheric profile systems), along with micrometeorological sensors, nitrate-related trace-gas analysers, and soil surface CO<sub>2</sub> flux systems, have been integrated into three 50-metre-tall towers facilitating studies on forest ecology and management in the Chinese Academy of Sciences Qingyuan Forest CERN Field Laboratory.

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 CO<sub>2</sub>/H<sub>2</sub>O/trace-gas fluxes over mountain forests (e.g. heterogeneous landscapes). It does this while collecting long-term data of the fluxes over the 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.

## CASE STUDY

### DELIVERING DATA – FLUX STUDIES OVER MOUNTAIN FORESTS

#### Qingyuan Forest CERN CAS

Qingyuan Forest CERN is a field laboratory directly supported 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), 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, dozens of projects with annual support of millions in US dollars are running here. Long-term, quality data to quantify the atmosphere (i.e. fluxes over forecasts), as influenced by forest growth and development under human disturbance, are indispensable in this laboratory (Zhu et al. 2018).

#### Integration of CPEC310 and AP200 Systems with Other Sensors

The field of mountain forests in Qingyuan Forest CERN over a heterogeneous landscape theoretically challenges the techniques of measuring fluxes that are commonly applicable to homogeneous 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 CO<sub>2</sub> flux systems compatible with CPEC310 and AP200 in system control and data sharing.

#### CPEC310

CPEC310 is a CPEC system from Campbell Scientific. Its CO<sub>2</sub>/H<sub>2</sub>O flux measurements are the benchmark used to assess the same 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<sub>2</sub>/H<sub>2</sub>O signals at high frequency (e.g. 10 Hz) is measured using a conventional, slower sensor (e.g. a model 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 time interval. This functionality regularly (via user settings) adjusts the zero and span parameters in the working equation of a CO<sub>2</sub>/H<sub>2</sub>O analyzer (LI-COR Biosciences 2016) to fit the temperature near where the system is running, which technically improves the accuracies of measurements for CO<sub>2</sub>/H<sub>2</sub>O 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, is the atmospheric profile system to measure  $\text{CO}_2/\text{H}_2\text{O}$ , 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 changes in  $\text{CO}_2/\text{H}_2\text{O}$  and heat storages between biosphere and atmosphere over the profile up to the CPEC310 level (e.g. 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 a fast response profile system with fluxes measured by a CPEC310, can greatly improve the reliability in an estimation of flux and even net ecosystem exchange (NEE, Wang et al. 2016a). This has been advocated recently by the International Carbon Observatory System to standardise the methodology for the storage term measurements to the system infrastructure (Montagnani et al. 2018). Similarly to the CPEC310, the AP200 also has two distinguishing advantages:

1. Functionality of auto-zero/span
2. EasyFlux-DL-CR1KXAP software (under development)



## Software

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, Oregon) and soil moisture and temperature measurements (models: CS655, TCAV, Campbell Scientific, Utah). These additions enable the AP200 to measure more variables of interest for comprehensive analyses.

## Micrometeorology Sensors

Each tower was equipped with the following sensors: a CNR4 four-component radiometer (Kipp & Zonen, Amsterdam) measures incoming and outgoing radiation (longwave and shortwave) over the forest canopy (Fig a); 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 b for one replication); SI-111 infrared radiometers measure surface temperature outside (Fig c1) and inside canopy (Fig c2); and a 52202 rain gauge (RM Young Company, Michigan) measures precipitation (Fig d).



## Soil $\text{CO}_2$ flux system and trace-gas flux system

Each tower was equipped with the following sensors: a soil surface  $\text{CO}_2$  flux system compatible with CPEC310 and AP200 in system control and data sharing has been designed for  $\text{CO}_2$  efflux from forest floor, and trace-gas analysis (TGA) (Campbell Scientific, Utah) 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 all systems installed in the three towers. CPEC310 has an option of valve and scrub modules for its best performance in auto-zero/span; AP200 has an option of a zero-gas bottle along with the maximum number of sampling intakes for its most reliable measurements; CNR4 has an option of CNF4 to acquire better data in evening, low wind, and moist conditions; and 52202 rain gauge has an option of a heating accessory for data availability in the winter season.

All sensors installed in the three towers are research grade for ecology. The CNR4 is a high-end, four-component radiometer; HFP01SC is the only soil heat flux plate with self-calibration capability for forests; and 52202 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<sub>2</sub> 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

Measuring flux and related studies in mountain forests over a heterogeneous landscape, such as Qingyuan Forest CERN, is challenging. 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) has been established. This laboratory organizes scientists from the Institute of Applied Ecology, other institutes under CAS, Campbell Scientific, Campbell Scientific (Beijing) Company Ltd, Shenyang Agricultural University, Northeast Forestry University, Beijing Techno Solutions Ltd, and foreign visiting scientists as a team.

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

The team has three goals: (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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