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## 1. General Information

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|---|---|
| Site name (three letter code) | Fuji Hokuroku Flux Observation Site (FHK) |
| Researcher #1 (e-mail) | Yoshiyuki Takahashi (yoshiyu@nies.go.jp) |
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| Researcher #2 (e-mail) | [Soil respiration] Naishen Liang (liang@nies.go.jp) |
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| Other Researchers (e-mail) | |
| Observation period | From January 2006 to present |
| Measurement frequency | Continuous |
| Infrastructure | Tower: 32 m<br>Electrical power: (AC)<br>Facilities for communication (Internet communication is available)<br>Accommodation (none) |
| Research fund #1 | |
| Research fund #2 | |
| Research fund #3 | |
| URL | https://db.cger.nies.go.jp/gem/en/flux/fuji.html |
| Other information | When this data set is referred to in publications, it should be cited in the following format.<br>Takahashi, Y. (2021), Micrometeorological $CO_2$ Flux Data at Fuji Hokuroku Flux Observation Site (FHK), Ver.x.x [*1],<br>NIES, DOI:10.17595/20210730.001, (Reference date[*2]: YYYY/MM/DD)<br>[*1] The version number is indicated in the name of each data file.<br>[*2] As the reference date, please indicate the date you downloaded the files. |

## 2. Site description

| | |
|---|---|
| Site name (three letter code) | Fuji Hokuroku Flux Observation Site (FHK) |
| Country | Japan |
| Location | Fujiyoshida City, Yamanashi Pref. |
| Latitude and Longitude (first decimal of second precision), Elevation (geographic coordinates, surveying method) | 35.443528°N, 138.764722ºE (1050-1150 m above sea level) |
| Slope | 3-4 deg |
| Terrain Type | Flat |
| Area | 150 ha |
| Fetch | |
| Climate<br>(Köppen Climate Classification) | Cool-temperate |
| Mean annual air temperature | 8.7 degree C (2006-2012, at a height of 2 m) |
| Mean annual precipitation | 1844 mm (2006-2012) |
| Vegetation Type | Deciduous needleleaf forest (Japanese larch afforestation) |
| Dominant Species (Overstory) | Japanese larch (*Larix kaempferi Sarg.*), evergreen needle-leafed species (*Pinus densiflora* and *Abies homolepis*), deciduous broad-leafed species (*Swida controversa, Quercus serrata, Quercus crispula, Betula platyphylla var. japonica, Prunus incisa,* etc.) |
| Dominant Species (Understory) | Ferns (*Dryopteris crassirhizoma*, *Dryopteris expansa*), bamboo grass (*Sasamorpha borealis*), and other herbs. |
| Canopy height | 20-26 m |
| Age | Around 70 years old (Planted around 1950) |
| LAI | Larch: 2.8 $m^2$ $m^{-2}$ estimated based on the leaf mass abundance (Okano & Arase 2007), and 2.4 $m^2$ $m^{-2}$ estimated based on 3D portable laser scanner measurement (Maki et al., 2012), Understory: 3.0 $m^2$ $m^{-2}$ (max) |
| Soil type | Coarse volcanic ash (Urakawa et al., 2015) |

# 3. Measurement Item
## 3-1. Meteorology

| Observation items | Levels / Depth | Instrument |
|---|---|---|
| Global solar radiation (incoming) | 32 m,<br>30 m | Pyranometer (MS-402F, EKO, Japan),<br>Radiometer (MR-50, EKO, Japan) |
| Transmitted solar radiation (below canopy incoming) | 2 m (five points)<br>2 m (two points) | Pyranometer (MS-601, EKO, Japan)<br>Radiometer (MR-50, EKO, Japan) |
| Global solar radiation (outgoing) | 30 m | Radiometer (MR-50, EKO, Japan) |
| Transmitted solar radiation (below canopy outgoing) | 2 m (two points) | Radiometer (MR-50, EKO, Japan) |
| Long-wave radiation (incoming) | 30 m | Radiometer (MR-50, EKO, Japan) |
| Transmitted long-wave radiation (below canopy incoming) | 2 m (two points) | Radiometer (MR-50, EKO, Japan) |
| Long-wave radiation (outgoing) | 30 m | Radiometer (MR-50, EKO, Japan) |
| Transmitted long-wave radiation (below canopy outgoing) | 2 m (two points) | Radiometer (MR-50, EKO, Japan) |
| Net radiation | 30 m, 2 m (two points) | Radiometer (MR-50, EKO, Japan) |
| PPFD (incoming) | 32 m | Quantum sensor (ML-020P, EKO, Japan) |
| Transmitted PAR (below canopy incoming) | 2 m (five points) | Quantum sensor (LI-190S, LI-COR (Jan.2006-Mar.2007), ML-020P; EKO (Mar.2007-)) |
| Reflected PAR (outgoing) | 30 m | Quantum sensor (LI-190S, LI-COR, Jan.2006-Aug.2008, ML-020P, EKO, Japan, Sep.2008-) |
| Reflected PAR (below canopy outgoing) | 2 m (three points) | Quantum sensor (LI-190S, LI-COR (Jan.2006-Mar.2007), ML-020P; EKO (Mar.2007-)) |
| Wind direction | 35 m | Three-dimensional sonic anemometer-thermometers (DA-600, Probe TR-61C (Jan. 1, 2006 – May 9, 2011); DA-650, Probe TR-61C (May 9, 2011 – Nov. 22, 2011); DA-600, Probe TR-61C (Nov. 22, 2011 – Apr. 18, 2012); DA-700, Probe TR-61A (Apr. 18, 2012 – Apr. 11, 2016), SONIC CORP.) |
| | 32, 27, 22, 16, 10, 4.5, 2 m | Sonic anemometer (MA-130A, EKO, Japan, Jan.2006-Mar.2007), (PGWS-100-3, GILL, Apr.2007-) |
| Wind speed | 35 m | Three-dimensional sonic anemometer-thermometers (DA-600, Probe TR-61C (Jan. 1, 2006 – May 9, 2011); DA-650, Probe TR-61C (May 9, 2011 – Nov. 22, 2011); DA-600, Probe TR-61C (Nov. 22, 2011 – Apr. 18, 2012); DA-700, Probe TR-61A (Apr. 18, 2012 – Apr. 11, 2016), SONIC CORP.) |
| | 32, 27, 22, 16, 10, 4.5, 2 m | Sonic anemometer (MA-130A, EKO, Japan, Jan.2006-Mar.2007), (PGWS-100-3, GILL, Apr.2007-) |
| Air temperature | 32, 27, 22, 16, 10, 4.5, 2, 1, 0.5 m | Platinum resistance thermometer and capacitive hygrometer (HMP-45D, Vaisala) |
| Relative humidity | 32, 27, 22, 16, 10, 4.5, 2, 1, 0.5 m | Platinum resistance thermometer and capacitive hygrometer (HMP-45D, Vaisala) |

| | | |
|---|---|---|
| Soil temperature | 0, 0.02, 0.05 m (three points),<br>0.15, 0.3, 0.6 m | Platinum resistance thermometer (C-PTWP, Climatec, Japan) |
| Ground heat flux | 0.02 m (three points) | Heat flux plate (PHF-01, REBS) |
| Soil water content | 0m (three points),<br>0.1, 0.2 m (two points) | TDR sensor (CS616, Campbell) |
| Barometric pressure | 1.5 m | Barometer (PTB210, Vaisala) |
| Precipitation | 32 m | Tipping-bucket rain-gauge with heater (CYG-52202, R. M. Young) |
| Snow depth | 2 m | Sonic ranging sensor (SR50, Campbell) |
| Spectral radiation (incoming)<br>Global, direct/diffuse, transmitted | 32,<br>2 m | Spectroradiometer (MS-700, EKO, Japan) and shadow band (32 m; PRB-100, PREDE, Japan) |
| Spectral radiation reflected, transmitted (outgoing) | 30,<br>2 m | Spectroradiometer (MS-700, EKO, Japan) |
| $CO_2$ concentration | 35, 32, 27,<br>22,16,10,4.5,2,1, 0.5 m | Closed-path $CO_2$/$H_2O$ analyzer (LI-6262, LI-COR) |

## 3-2. Eddy correlation method (CO$_2$)

| | |
|---|---|
| System | Open- and closed-path systems ($CO_2$ flux, latent heat flux) |
| Wind speed | Three-dimensional sonic anemometer-thermometers:<br>DA-600-3TV, Probe TR-61C, SONIC CORP. (Jan. 1, 2006 – May 9, 2011),<br>DA-650-3TV, Probe TR-61C, SONIC CORP. (May 9, 2011 – Nov. 22, 2011),<br>DA-600-3TV, Probe TR-61C, SONIC CORP. (Nov. 22, 2011 – Apr. 18, 2012),<br>DA-700-3TV, Probe TR-61A, SONIC CORP. (Apr. 18, 2012 – Apr. 11, 2016) |
| Air temperature | Platinum resistance thermometer and capacitive hygrometer, HMP45A, Vaisala |
| Water vapor | Open-path $CO_2$/$H_2O$ analyzer, LI-7500, LI-COR (Jan. 1, 2006 –)<br>Closed-path $CO_2$/$H_2O$ analyzers, LI-6262, LI-COR (Jan. 1, 2006 – Apr. 11, 2016)<br>Platinum resistance thermometer and capacitive hygrometer (HMP45A, Vaisala) |
| $CO_2$ | Open-path $CO_2$/$H_2O$ analyzer, LI-7500, LI-COR (Jan. 1, 2006 –)<br>Closed-path $CO_2$/$H_2O$ analyzers, LI-6262, LI-COR (Jan. 1, 2006 – Apr. 11, 2016) |
| Measurement height | 35m |
| Sampling frequency | 10 Hz |
| Averaging time | 30 min |
| Data logger | DR-M3, TEAC, Japan (Jan. 2006 – March 2012); CR-23X, Campbell Scientific, USA (Jan. 2006 – April 2008); CR-3000, Campbell Scientific, USA (May 2008-) |
| Data storage | MO (TEAC); Data-logger CR-3000, Campbell Scientific, USA |
| Original data (Raw data or statistics) | Raw data |
| | |

## 3-3. Fluxes of non-CO$_2$ gases

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|---|---|
| Gas | $CH_4$ |
| Method | Hyperbolic relaxed eddy accumulation (HREA) method with a laser-based analyzer (GGA-24r-EP, Los GatosResearch Inc., USA), from Aug. 2011 to Sep. 2012 (Ueyama et al., 2013)<br>Automated dynamic closed (non-steady-state through-flow) chambers with a laser-based analyzer (GGA-24r-EP), from Oct. 2012 (Ueyama et al., 2015) |
| Measurement height | 35, 28, 18, 5, and 0.3 m (HREA method), 0 m (chambers) |
| Data logger | Laptop PC via serial communication |
| Data storage | |

## 3-4. Soil respiration

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|---|---|
| Measurement method | Automated dynamic closed chamber method (flow-through, non-steady-state design using IRGA and Integrated Cavity Output Spectroscopy ($CH_4$/$CO_2$)) |

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|---|---|
| Reference(s) for method (if have) | Teramoto M., Liang N., Takahashi Y., Zeng J., Saigusa N., Ide R., Zhao X., 2019: Enhanced understory carbon flux components and robustness of net $CO_2$ exchange after thinning in a larch forest in central Japan. *Agricultural and Forest Meteorology*, 274, 106–117.<br>Teramoto M., Liang N., Zeng J., Saigusa N., Takahashi Y., 2017: Long-term chamber measurements reveal strong impacts of soil temperature on seasonal and inter-annual variation in understory $CO_2$ fluxes in a Japanese larch (*Larix kaempferi Sarg.*) forest. *Agricultural and Forest Meteorology*, 247, 194–206. |
| Measuring system | A 24-channel automated chamber system (home-made by the investigator) |
| IRGA<br>Integrated Cavity Output Spectroscopy | Li-820 (Li-Cor)<br>UGGA (LGR) |
| Flow control | High-precision flow transducer (FSM-V, CKD) and manual flow regulator |
| Chamber type | Clear PVC chamber |
| Chamber size | 90 cm in length × 90 cm in width ×50 cm in height (8 chambers for soil respiration and 8 chambers for heterotrophic respiration), and 90 cm in length × 90 cm in width × 100 cm in height (8 chambers for net understory $CO_2$ exchange). |
| Number of chambers | 24 |
| Measuring intervals | The measurement period, during which the chamber lids were closed, was 2.5 min for each chamber (with data recorded at 10-s intervals using CR1000 datalogger (Campbell Scientific Inc.)) from 2006 to 2009. The measurement period was 5.0 min from 2010 on. |
| Is the ground covered by snow in winter? (if yes, how about the measurement in winter? | Yes. Missing soil $CO_2$ efflux data (gaps) during snow covered period were estimated based on Lloyd and Taylor equation for each chamber. |
| Original data (Raw data or statistics) | Raw data |
| Air temperature collection (if done, which temperature was used?) | Air temperature inside each chamber was measured using the home-made T-Type thermocouple. |
| Soil temperature collection (if done, which temperature was used?) | Soil temperature at the depth of 5-cm inside each chamber was measured using the home-made T-Type thermocouple. |
| Air pressure collection (if done, which sensor was used?) | Air pressure was measured using PX2760 (Omega Engineering). |
| Understory PPFD collection | 6 sensors (SQ225; Apogee Instruments Inc.) at the height of 1 m around plant chambers |
| Soil moisture collection (if done, which sensor was used?) | 6 CS616 (Campbell Scientific Inc.) were used for monitoring soil moisture at the depth of 10 cm in 6 randomly selected chambers (two chambers for each treatment). |

## 3-5. Other

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|---|---|
| Photosynthesis | Occasionally |
| Ecological Investigation | Tree heights, stand density, diameter, biomass, LAI |
| Phenology | Continuous (photos) |

## 4. Note (e. g. calibration information, Publications)

### Calibration information

Open-path analyzers were calibrated approximately every two months with standard $CO_2$ gases and a dew point generator (LI610, LI-COR).

The gain of $CO_2$ of the closed-path analyzers was checked once a day by flowing two standard $CO_2$ gases of 320 ppmv and 420 ppmv that were automatically controlled using a programmable data logger (CR23X during 2006-mid-2007 and CR3000 after that, both were made by , Campbell Scientific, Logan, UT, USA.

## Publications

Okano T., Arase T. 2007: Biomass measurement of larch forest in Fuji Hokuroku Flux Research Site, *Annual Report of Global Environment Monitoring H19*, Center for Global Environmental Research, National Institute for Environmental Studies. (in Japanese)

Arase T. 2012: Estimation of Seasonal Changes in the Biomass of Forest Floor Vegetation in a Larch Forest at the Northern Foot of Mt. Fuji, Japan. *Journal of Environmental Information Science*, 40-5, 23-30.

Maki M., Takahashi A., Okano T., Oguma H. 2012: Development of the method to estimate light environment on forest floor using 3D portable laser scanner and radiative transfer model. *Journal of The Remote Sensing Society of Japan*, 32-2, 77-87.

Ueyama M., Takai Y., Takahashi Y., Ide R., Hamotani K., Kosugi Y., Takahashi K., Saigusa N. 2013: High-precision measurements of the methane flux over a larch forest based on a hyperbolic relaxed eddy accumulation method using a laser spectrometer. *Agricultural and Forest Meteorology,* 178, 183-193.

Mochizuki T., Tani A., Takahashi Y., Saigusa N., Ueyama M. 2014: Long-term measurement of terpenoid flux above a *Larix kaempferi* forest using a relaxed eddy accumulation method. *Atmospheric Environment* 83, 53-61.

Ueyama M., Takanashi S., Takahashi Y. 2014 Inferring methane fluxes at a larch forest using Lagrangian, Eulerian, and hybrid inverse models. *Journal of Geophysical Research: Biogeosciences*, 119 (10), 2018-2031.

Urakawa R., Ohte N., Shibata H., Tateno R., Hishi T., Fukushima K., Inagaki Y., Hirai K., Oda T., Oyanagi N., Nakata M., Toda H., Kenta T., Fukuzawa K., Watanabe T., Tokuchi N., Nakaji T., Saigusa N., Yamao Y., Nakanishi A., Enoki T., Ugawa S., Hayakawa A., Kotani A., Kuroiwa M., Isobe K. 2015: Biogeochemical nitrogen properties of forest soils in the Japanese archipelago. *Ecological Research*, 30(1), 1-2.

Ueyama M., Takeuchi R., Takahashi Y., Ide R., Ataka M., Kosugi Y., Takahashi K., Saigusa N. 2015: Methane uptake in a temperate forest soil using continuous closed-chamber measurements. *Agricultural and Forest Meteorology,* 213, 1-9.

Takahashi Y., Saigusa N., Hirata R., Ide R., Fujinuma Y., Okano T., Asarse T., 2015: Characteristics of temporal variations in ecosystem $CO_2$ exchange in a temperate deciduous needle-leaf forest in the foothills of a high mountain. *Journal of Agricultural Meteorology*, 71(4), 302-317.

Mochizuki T., Miyazaki Y., Ono K., Wada R., Takahashi Y., Saigusa N., Kawamura K., Tani A. 2015: Emissions of biogenic volatile organic compounds and subsequent formation of secondary organic aerosols in a *Larix kaempferi* forest. *Atmospheric Chemistry and Physics*, 15, 1-13.

Urakawa R., Ohte N., Shibata H., Isobe K., Tateno R., Oda T., Hishi T., Fukushima K., Inagaki Y., Hirai K., Oyanagi N., Nakata M., Toda H., Kenta T., Kuroiwa M., Watanabe T., Fukuzawa K., Tokuchi N., Ugawa S., Enoki T., Nakanishi A., Saigusa N., Yamao Y., Kotani A. 2016: Factors contributing to soil nitrogen mineralization and nitrification rates of forest soils in the Japanese archipelago. *Forest Ecology and Management*, 361, 382-396.

Ide R., Hirose Y., Oguma H., Saigusa N. 2016: Development of a masking device to exclude contaminated reflection during tower-based measurements of spectral reflectance from a vegetation canopy. *Agricultural and Forest Meteorology*, 223, 141-150.

Teramoto M., Liang N., Zeng J., Saigusa N., Takahashi Y., 2017: Long-term chamber measurements reveal strong impacts of soil temperature on seasonal and inter-annual variation in understory $CO_2$ fluxes in a Japanese larch (*Larix kaempferi Sarg.*) forest. *Agricultural and Forest Meteorology*, 247, 194-206.

Teramoto M., Liang N., Takahashi Y., Zeng J., Saigusa N., Ide R., Xin Zhao 2019: Enhanced understory carbon flux components and robustness of net $CO_2$ exchange after thinning in a larch forest in central Japan. *Agricultural and Forest Meteorology*, 274, 106-117.