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ABC-IS Forest Flux Station

Report on Instrumentation, Operational Testing and First Months of Measurements

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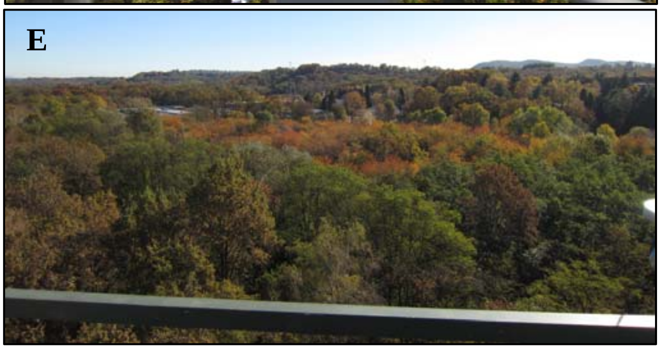

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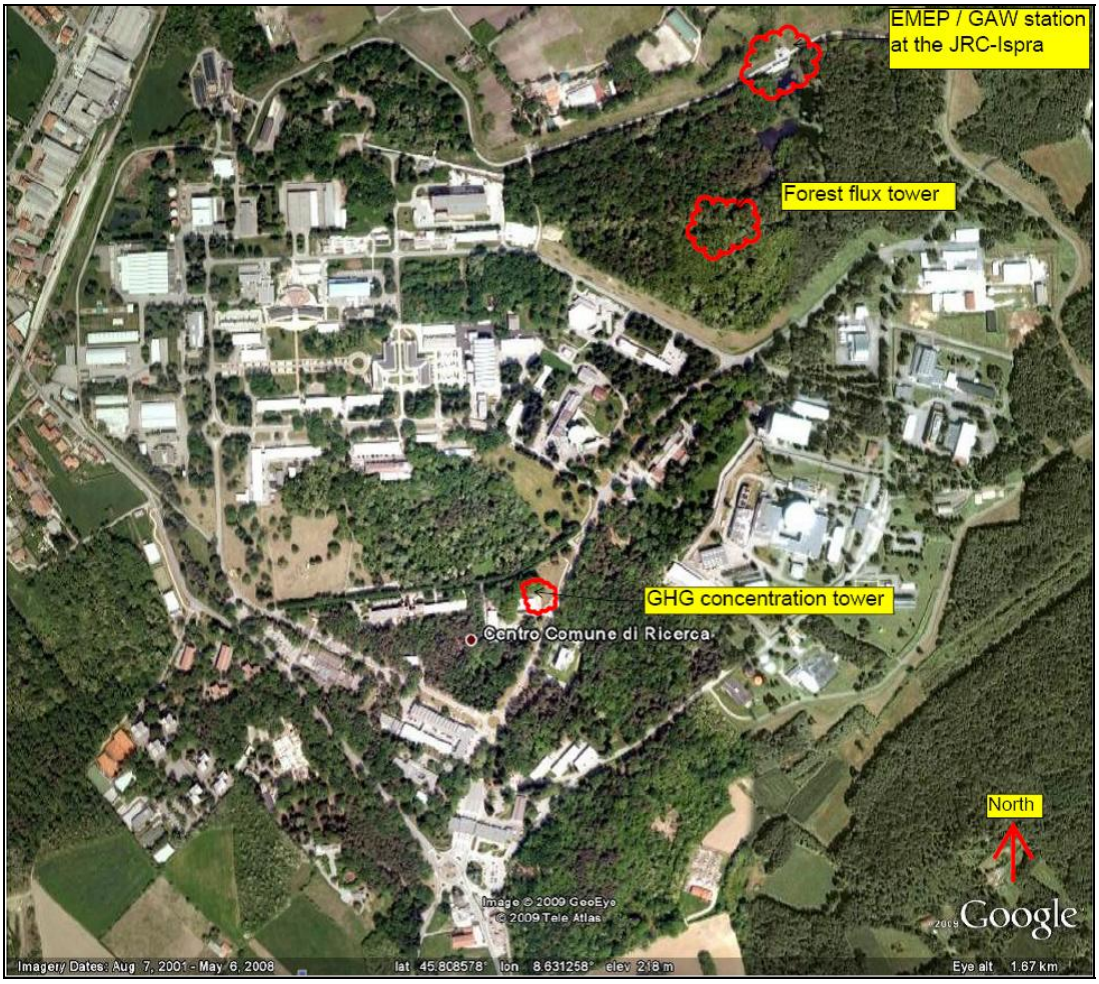
Objective

The objective of this report is the presentation of status the ABC-IS Forest Flux Station in terms of installation of instruments, operational testing and first months of measurements.

As described in full extend in the Project Document ABC-IS forest flux tower (ARES(2011)1288711), the then Climate Change and Air Quality Unit's, now Air and Climate Unit (ACU), started to develop a forest flux station on the JRC Ispra site (see Pic. 1 for its location) and in 2012 this project has advanced significantly. After the erection of a 36 m high self-standing tower (see Fig. 1 for its design) in November 2011, the infrastructure, notably electricity, IT services and air conditioning in the adjacent container have been set up in the first quarter of 2012. Thereafter, the installation and testing of scientific instrumentation both on the tower and at the ground has started in view of the two projects the station participates in, i.e. the ESFRI initiative ICOS (International Carbon Observation System) and the FP7 project ECLAIRE (Effects of Climate Change on Air Pollution and Response Strategies for European Ecosystems).



Pic. 1: Location of the forest flux tower on the JRC-Ispra site relative to the other ABC-IS locations (GHG concentration tower and EMEP/GAW station).

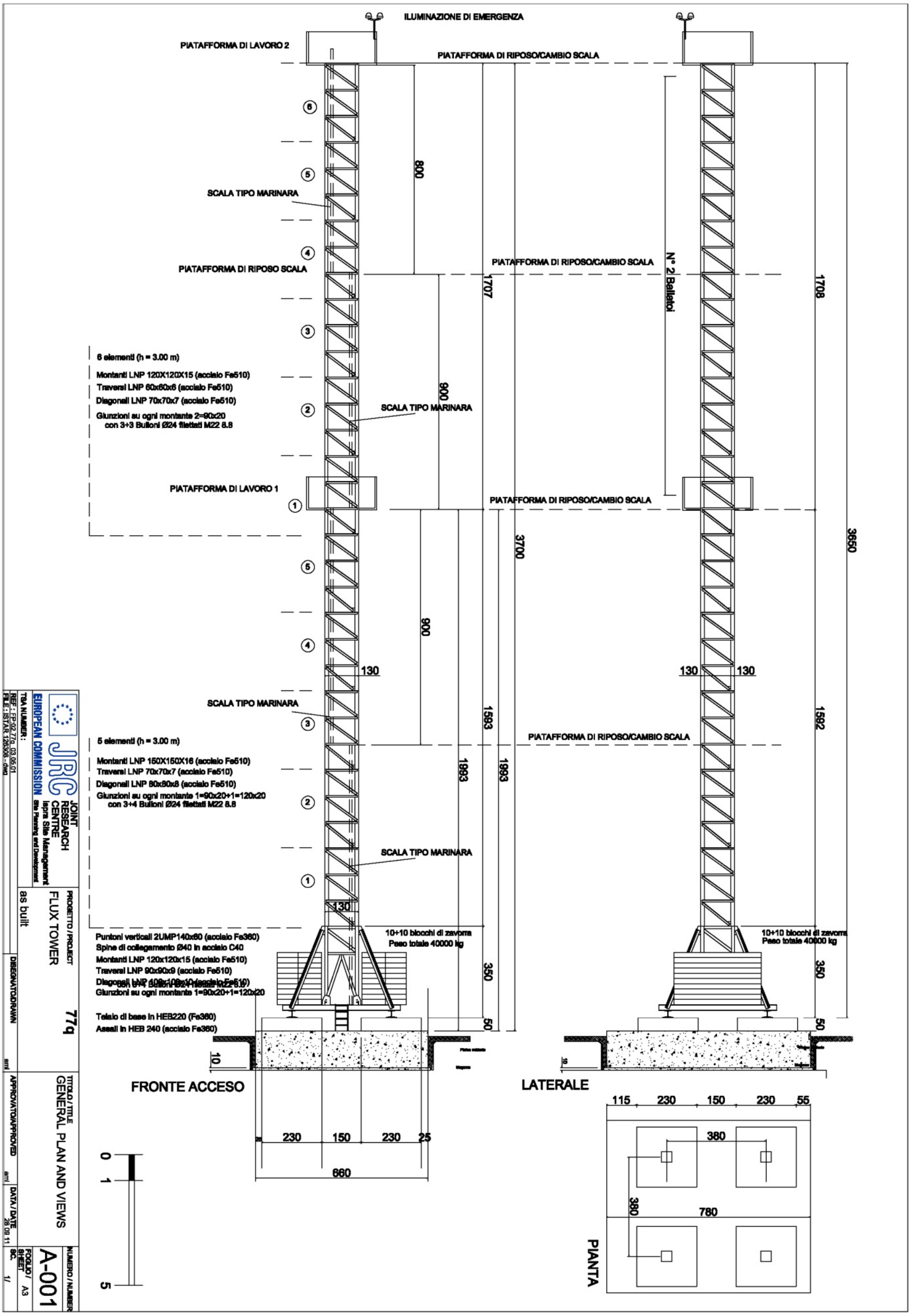


Fig. 1: Design of the forest flux tower.

Setup of instrumentation

An up-to-date list of instruments installed at the ABC-IS forest flux station in 2012, together with the parameters they measure, is maintained in the 'handbook of instruments' sheet of the logbook file 'ABC-IS forest tower logbook.xls' located at '\\Ccunas3\Laboratories\GHG\GHG_fluxes\ABC-IS Forest\QMS & Minutes'. Tab. 1 gives a summary of the instrumentation installed and running in 2012. In addition, on a 34 point grid covering approximately the footprint of the tower, litter collection, soil respiration measurements are made and hemispheric pictures for LAI calculation are taken regularly. Results of these measurements are not shown in this document.

Tab. 1: Instruments installed and running continuously at the ABC-IS forest flux station in 2012 on the tower top (light blue) and forest ground (light brown).

Instrument	Name and make	Measured parameters	Project affiliations
Sonic anemometer	HS-50 – Gill	3D wind vectors	ICOS / ECLAIRE
IRGA	Li-7200 - LiCor	CO_2, H_2O fluxes	ICOS / ECLAIRE
Fast ozone sensor	FOS – Sextant	O_3 fluxes in arbitrary units	ECLAIRE
Slow ozone sensor	49C – Thermo	O_3 concentration for flux calibration	ECLAIRE
Combined meteo sensor	WXT510 - Vaisala	P, T, RH, Rain, 2D wind vectors	ICOS / ECLAIRE
Net radiometer	CNR1 – Kipp & Zonen	short / long wavelength incoming / outgoing radiation	ICOS / ECLAIRE
Photosynthetic active radiation	BF5 – Delta-T SQL-110-L-10 – Apogee	PAR total / diffuse incoming, total outgoing	ICOS / ECLAIRE
Surface / leaf wetness sensors	SW120D – Burrage	surface and leaf wetness	ECLAIRE
Diver	Micro-Diver DI601 – SWS	Ground water level	ICOS / ECLAIRE
Soil temperature profile	Th3-v – UMS	Soil temperature profile	ICOS / ECLAIRE
Soil water profile	Trime-EZ – IMKO	Soil water profile	ICOS / ECLAIRE
Heat flux plates	HFP01 – Hukseflux	Soil heat flux	ICOS / ECLAIRE
Automated dynamic chamber system	JRC built	Soil NO / NO_2 flux	ECLAIRE

Instrument testing and comparison with measurements at the EMEP site

To the extent possible, measurements from the ABC-IS forest flux site have been compared to the data obtained at the ABC-IS / EMEP site during the first weeks of the operation of the respective instrument to validate its proper functioning. As the two measurement places are separated by a distance of approximately 250 m horizontally and 35 m vertically, certain differences of e.g. meteorological parameters such as temperature, relative humidity are expected, for pressure the difference can actually be calculated. This type of validation or any other form of direct validation is unfortunately not possible for a large fraction of the main parameters that are calculated such as fluxes.

All data presented in this paragraph are 10 minutes averages for both data measured at the ABC-IS forest tower site and at the EMEP site.

Comparison of the timelines of meteorological data from the EMEP site and the tower top are shown on Fig. 2 for temperature, relative humidity, wind speed and short wave solar radiation. They indicate a good agreement taking the separation of these two locations into account. Regarding temperature, the daytime high is slightly higher at the EMEP site compared to the tower top, whereas it is opposite for the night time lows. Relative humidity is significantly higher at the EMEP site during the night, mainly driven by the temperature difference of the two locations. The wind speed is generally higher at the tower top, as expected due to the different measurement heights. The short wavelength solar radiation agrees very well, as expected. Small differences, difficult to see on this plot, originate from shadowing of trees on the sensor at the EMEP site in the early morning and just before sunset.
Focusing on periods with high wind speeds, e.g. 25.6., 13.7.17.7., one clearly observes a better agreement of temperature and thus relative humidity. This indicates a strong mixing of the lowermost part of the atmosphere (0-36 meters) during those periods. At other times, especially during nights and caused by the generally slow wind speeds, the atmosphere is not well mixed and thus temperature and relative humidity differ at the two locations.

On Fig. 3, the pressure measurements are shown as timelines and scatter plot. The pressure difference obviously originates from the height difference of the two. Using the barometric height formula $dp/dh = -pMg/RT$ and assuming a constant temperature profile (simplifying the situation slightly), the calculated height difference is 30.5 meters, which agrees very well with the estimated one of 30 m (38 m for sensor on tower top plus 2 m terrain difference minus 10 m height at EMEP station).

A comparison of ozone concentration measurements performed at the EMEP site with the ones from the forest tower top are shown in Fig. 4, together with the wind speed again. One observes generally strong correlations of these measurements during the day (daytime high values at the ground are slightly higher than at the tower top) and a large difference during the night. Night time low values at the ground go down to 2-5 ppb, whereas at the tower top they remain between 15-30 ppb. Looking at the wind speed data in Fig. 4, one observes during strong wind periods (e.g. 28.-29.7., 5.-6.8.) also at night a very good agreement of the ozone data taken at the ground and the tower top. This leads to the conclusion, as with the temperature and relative humidity measurements earlier in this paragraph, that the lowermost part of the atmosphere is generally not well mixed. Only during periods with strong winds the atmosphere is sufficiently mixed that ozone concentrations at 38 m agree very well with measurements at the ground.

As pointed out earlier, flux measurements cannot be validated in the same manner as the meteorological measurements done before, so these measurements will be only presented as timelines in the following paragraph together with soil parameters.

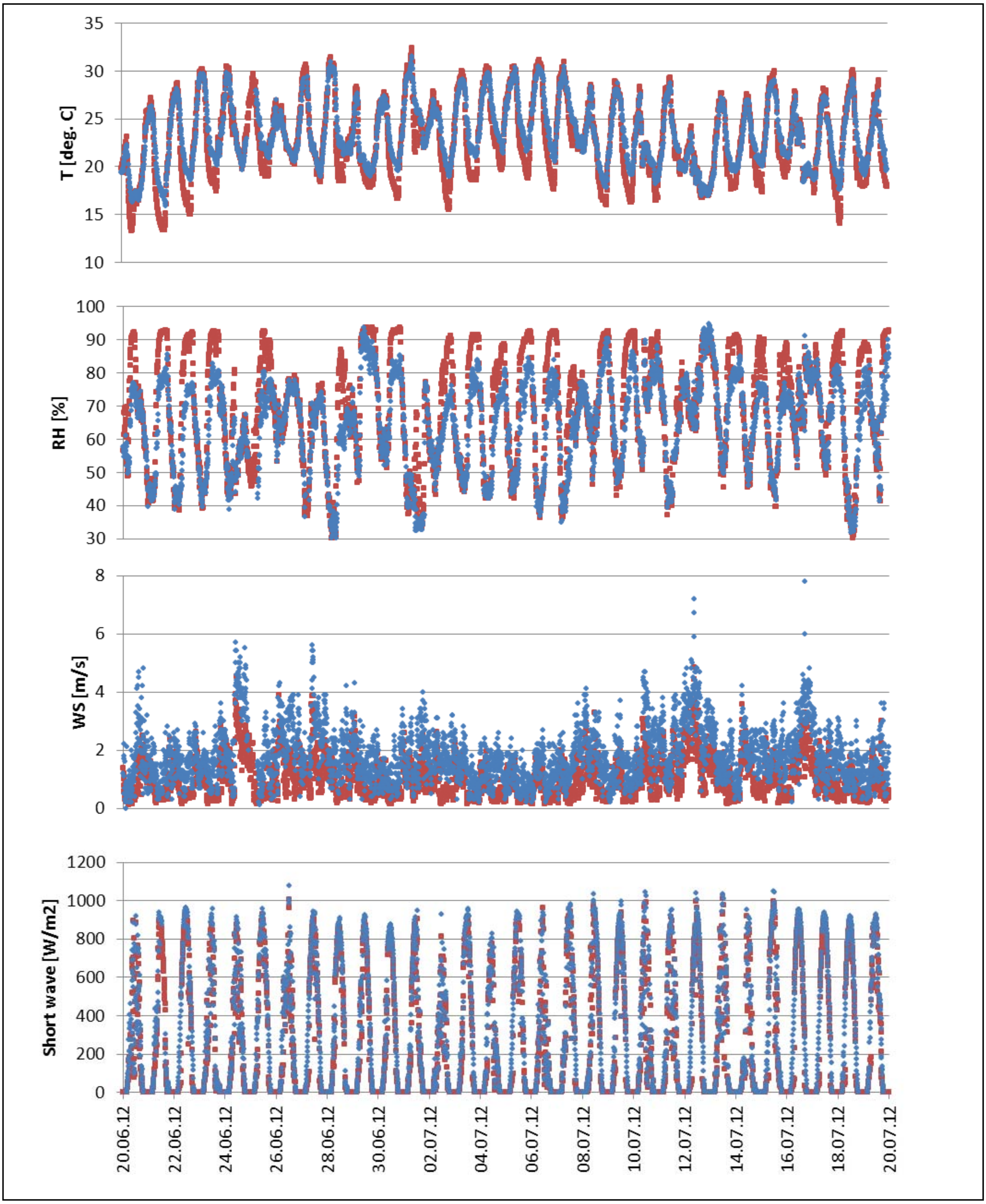


Fig. 2: Comparison of the timelines of measured data from the tower top (blue) and at the EMEP station (red). Parameters are temperature (top), relative humidity, wind speed and short wavelength incoming radiation (bottom).

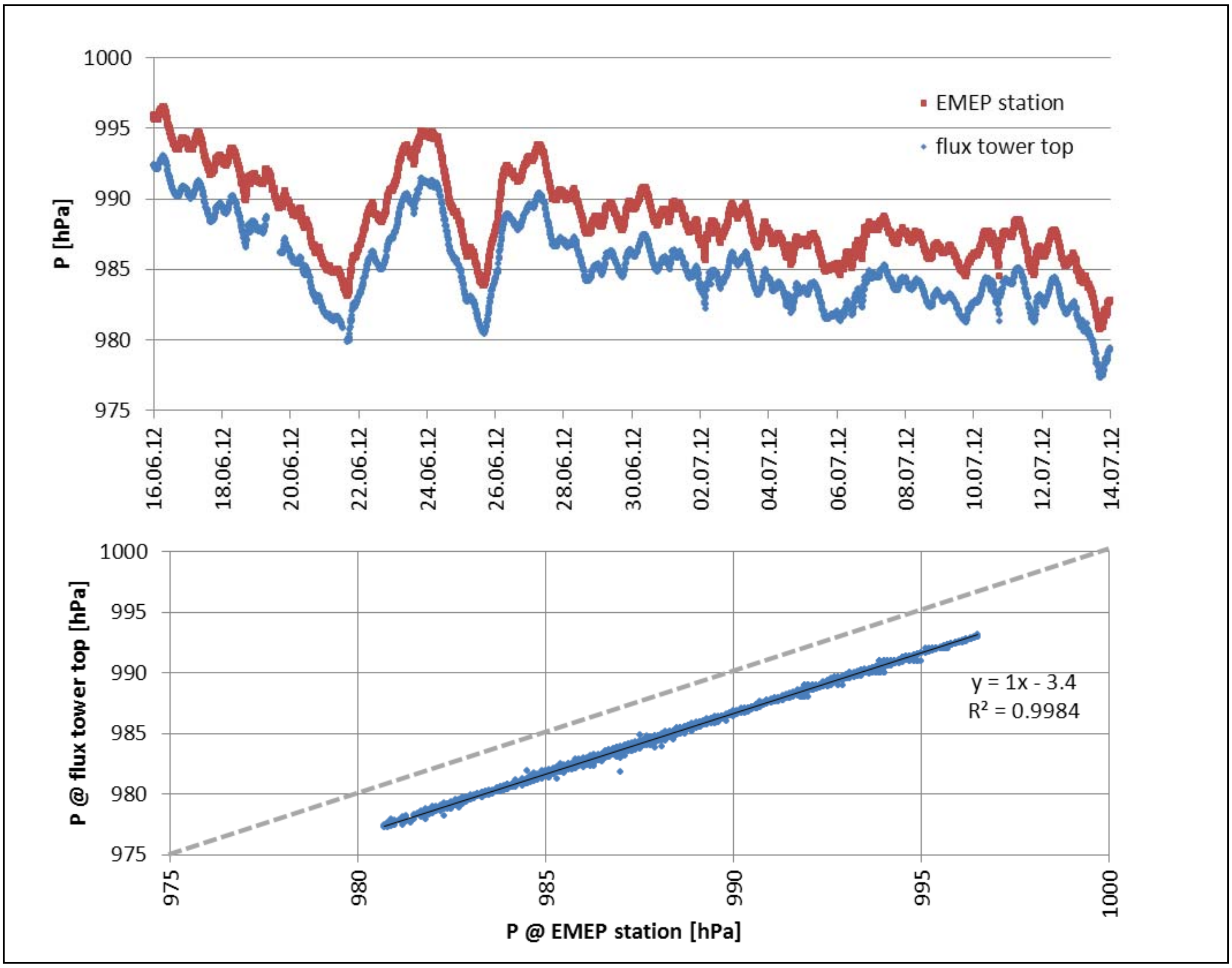


Fig. 3: Comparison of pressure measurements at the EMEP station and the tower top at the flux station, timelines on top and scatter plot on bottom (dashed 1-to-1 line as guide for the eye).

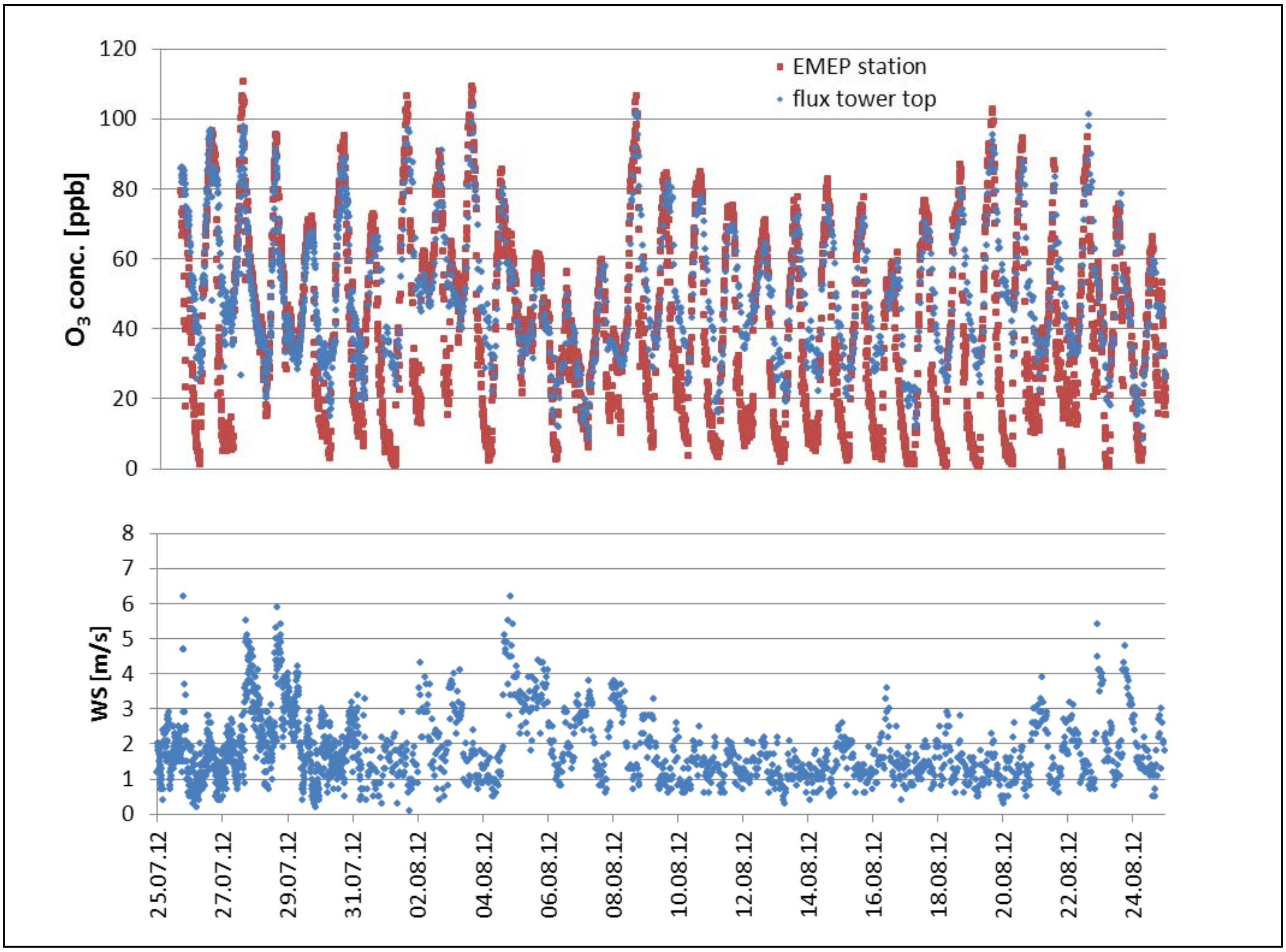


Fig. 4: Timelines of ozone concentration measurements at the tower top and the EMEP site (top) and wind speed (bottom).

Timelines of measured data in 2012

Data presented here as simple timelines of on-going measurements until 10th of November that are not final quality checked and assured datasets. Thus there may be data points included that are simple outliers or periods of malfunctioning of the instruments. Therefore, as it is the scope of this report, this paragraph presents an overview of data acquired so far at the ABC-IS Forest Flux Station which have not been discussed in the previous paragraph. Data presented here are 30 minutes averages unless stated otherwise.

Soil data measured at the site are shown in Fig. 5. In the top plot, the soil temperature with measuring points at 5, 10, 20, 30, 50 and 100 cm below the surface are presented. The temperature curves at the uppermost layers follow their expected diurnal cycle, comparing all depths one observes the changes from summer to autumn. The three spikes before September coincide with significant rain events and originate probably from water flowing down the measurement system that has been installed into the soil only in July. The contact between the soil and the profile system was not tight enough yet to prevent this flow of water.

The second plot depicts the soil water content profile with two replicates at 10 cm below surface. The peaks, especially for the measurement points at 50 cm and above, are due to rain events that occurred during the measurement period and wetted the soil. The lowermost measurement point at 100 cm below the surface indicates quite low soil water content below 15 % for most of the observation period. Looking also at the water table, measured as depth below the surface (last plot of Fig. 5, note also the different time scales), that shows a very low water table of 250 to 225 cm, one clearly sees that the summer / autumn 2012 was a very dry period.
The last but one plot of Fig. 5 displays the soil heat flux measured during the observation period with two replicate sensors at a depth of 10 cm, positive values indicate a heating up of the soil, negative one a cooling down.

The timelines of 30 minute averages of CO_2, energy and O_3 fluxes calculated from measured data using EdiRe and following the Carboeurope methodology (no correction for storage) are shown in Fig. 6: from top to bottom FC – CO_2 flux plus its cumulated value, H – sensible heat flux, LE – latent heat flux, FO_3 – O_3 flux plus its cumulated flux (please note the different time period for FO_3). As mentioned earlier, the data are not quality checked, meaning that all measurement points are included in these plots, and thus also night time fluxes that might be erroneous due to low turbulence are included.
From the FC plot and the cumulated values one clearly observes the period when the forest acts as a CO_2 sink, i.e. until early October, when photosynthesis and ecosystem respiration are approximately balanced, early October until early November, and since then the respiration dominates, turning the forest into a CO_2 source. The heat fluxes H and LE show a seasonal behaviour as well with higher values during the summer period and lower during winter.
O_3 fluxes were measured since August and indicate that the forest is a significant sink for ozone during the entire measurement period. Since early October, the O_3 flux values become lower. This coincides with a lower ozone concentration in the atmosphere compared to the situation in the summer, the reduction of air uptake by the trees and the autumnal leaf loss of the trees.

An assessment of the applicability of the eddy covariance (EC) method to measure fluxes at any time is given by the stationarity and integral turbulence tests. They are combined in the Carboeurope methodology into a quality flag (QF) for every data point. A value of 0 indicates strong turbulence and good stationarity, giving reliable EC flux values. A QF = 1 indicates acceptable quality and flux data with QF = 2 are unreliable and thus should not be used in further calculations.
For the measurements at the ABC-IS station, the distribution of quality flags for all flux data are given in Tab. 2. The table shows that 63 – 68 % of the data depending on the flux type are usable for further data evaluation and interpretation.

Tab. 2: Total number of flux data points and percentage of data points with quality flags according to the Carboeurope methodology.

	H [%]	LE [%]	FC [%]	FO_3 [%]
data points	6267	6267	6267	4823
QF = 0	13	10	12	10
QF = 1	55	53	52	54
QF = 2	32	37	36	36

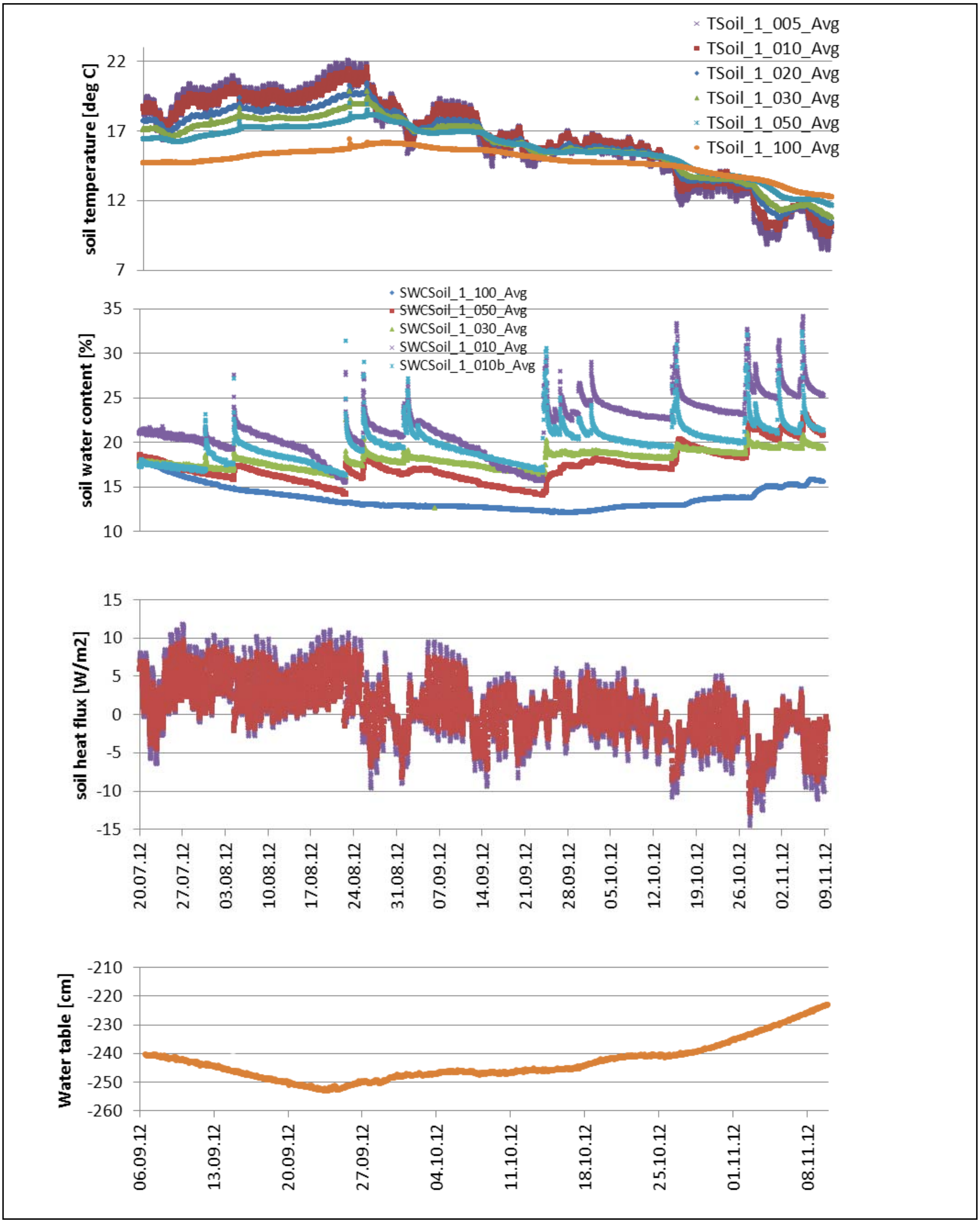


Fig. 5: Timeline of soil parameters measured at the ABC-IS forest flux site from top to bottom: soil temperature profile, soil water content profile, soil heat flux at two replicates (10 cm below surface) and water table below surface.

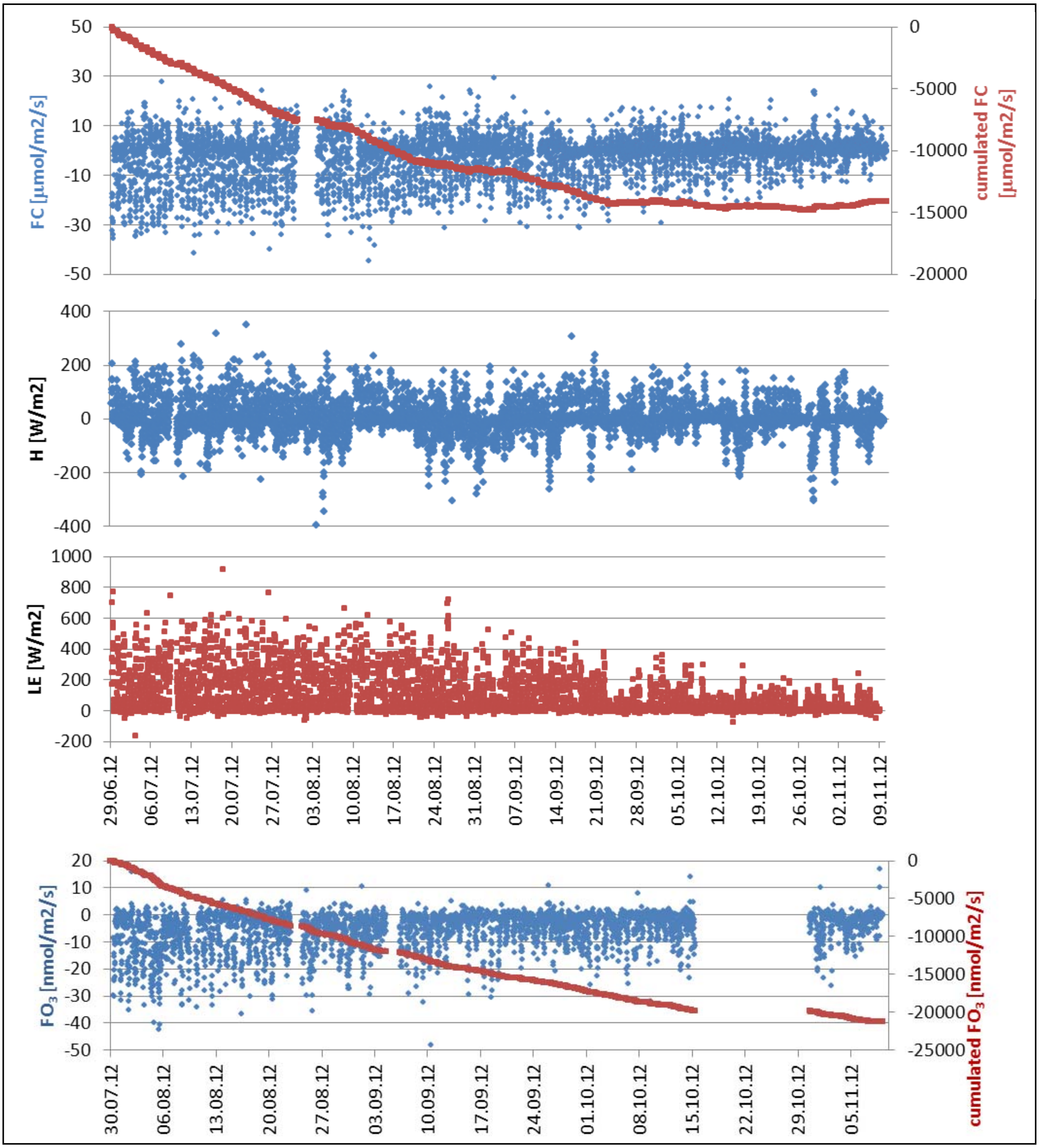
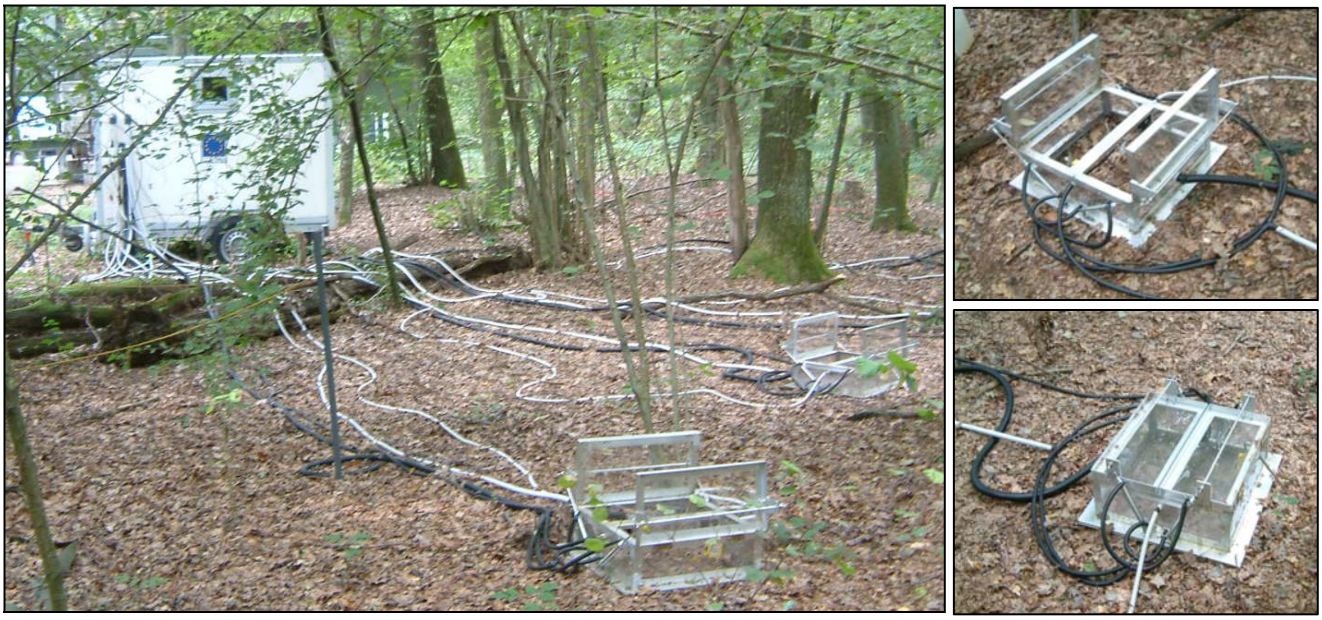


Fig. 6: Timelines of 30 minute fluxes calculated from data measured at the ABC-IS forest flux site, from top to bottom: CO_2 flux & cumulated values, sensible heat flux, latent heat flux and ozone flux & cumulated values.

An automated dynamic chamber system – soil NO & NO_2 fluxes

During 2012, an automated dynamic chamber system to measure NO & NO_2 fluxes from the soil has been developed at the JRC and subsequently deployed at the ABC-IS forest flux site (see Pic. 2). The setup consists of 5 replicate chambers measuring soil fluxes and one chamber that is closed to the ground and thus serves as a measurement blank. The analysers, pumps, control and data acquisition systems are installed in a small trailer.



Pic. 2: Chamber system to measure NO & NO_2 fluxes from soil at the ABC-IS forest flux site.

A detailed description of the system with its setup, functioning and data processing is beyond the scope of this report and therefore only a brief overview is given here. During a measurement cycle, the lids of one chamber are closed and the chamber is flushed with approx. 55 l/min for 6 minutes. At the same time, the concentrations of NO, NO_2 are measured at the outflowing air of chamber. The values of the first 3 minutes of each 6 minutes cycle are always discarded to allow for flushing and stabilization of the system. To account for concentration changes due to the reaction $NO + O_3 \rightarrow NO_2 + O_2$ in the chamber and sampling lines, the concentration of O_3 is measured as well. Combining the measured concentrations, air flow and chamber size, raw soil fluxes of NO and NO_2 are calculated. To account for chamber and sampling artefacts, the blank chamber, whose bottom part is closed to the ground, is measured in the same way before and after each soil chamber and the flux values calculated from that blank chamber are subtracted from the raw soil fluxes.
The NO and NO_2 soil flux data from 4 weeks of measurements are shown in Fig. 7. Each data point corresponds to a 3 minute average. As with all previous data, these are very preliminary results of on-going work. One can nevertheless already observe that the soil is a source for NO and a sink for NO_2 with significant differences between the different chamber positions. The data gap between 23.9. and 24.9. is due to an intense rain event and following that rain the NO / NO_2 flux behaviour of the soils under the different chambers changed notably.

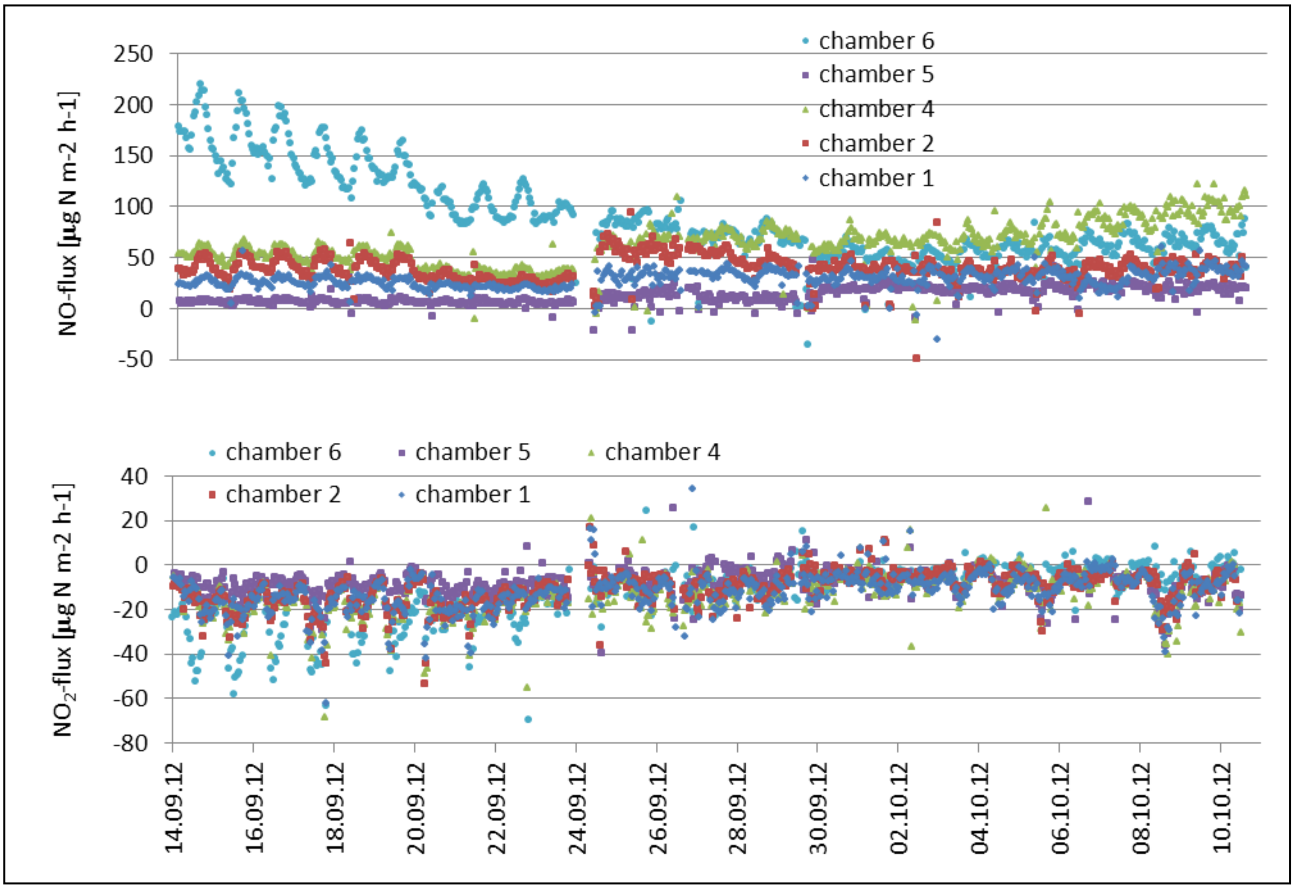


Fig. 7: Flavour of NO & NO_2 soil flux data obtained with the automated dynamic chamber system. Chamber # 3 is the blank chamber.

QMS related remark & resources

Several management related documents and repositories regarding the ABC-IS Forest Flux Station are maintained. The location and contents of these files and directories are summarized in Tab. 3; the root directory location is always \\ccunas3.jrc.it\laboratories\GHG\GHG_fluxes.

Tab. 3: Management related documents, their content and location.

<table>
<tr><th colspan="2">Content</th><th>Location directory</th><th>File name</th></tr>
<tr><td colspan="2">Electronic logbook of the ABC-IS Forest Flux Station including handbook of instruments installed</td><td>..\ ABC-IS Forest\QMS & Minutes</td><td>ABC-IS forest tower logbook.xls</td></tr>
<tr><td colspan="2">Logbook containing details regarding non-continuous measurements, e.g. LAI, soil respiration</td><td>..\ ABC-IS Forest\QMS & Minutes</td><td>ABC-IS forest logbook_ancillary measurements.xls</td></tr>
<tr><td colspan="2">Local TCP/IP network details</td><td>..\ ABC-IS Forest\QMS & Minutes</td><td>PC & LAN 77q.xlsx</td></tr>
<tr><td colspan="2">Description of data acquisition, data storage and data pre-processing</td><td>.. \QMS & Instrumentation\Life Cycle Sheets & SOPs</td><td>Data Acquisition_Storage_pre-Processing_ABC-IS Forest-SOP.doc</td></tr>
<tr><td colspan="2">SOP for the remote connection to the ABC-IS forest flux tower station’s local IP network</td><td>.. \QMS & Instrumentation\Life Cycle Sheets & SOPs</td><td>Remote connection flux tower-SOP.doc</td></tr>
<tr><td colspan="2">Life cycle sheets for various instruments</td><td>.. \QMS & Instrumentation\Life Cycle Sheets & SOPs</td><td></td></tr>
<tr><td colspan="2">Source code of programs for data loggers running at the site</td><td>…\ABC-IS Forest\QMS & Minutes\DataLogger_Programs</td><td></td></tr>
<tr><td colspan="2">Collection of manuals for instruments</td><td>..\GHG_fluxes\QMS & Instrumentation\Manuals</td><td></td></tr>
<tr><td rowspan="2">Minutes of meetings regarding</td><td>ECLAIRE</td><td>…\GHG_fluxes\ABC-IS Forest\ECLAIRE Docs</td><td></td></tr>
<tr><td>GHG laboratory</td><td>…\GHG_fluxes\QMS & Instrumentation\Minutes</td><td></td></tr>
</table>

Outlook & summary

In order to make the ABC-IS Forest Flux Station fully compliant with the requirements for ICOS Ecosystem Station Level 2 sites, some work is foreseen and needs to be executed in 2013. This consists mainly of the installation (and partly the procurement) of monitoring equipment to:

- measure temperature, relative humidity and CO_2 concentration profiles along the tower
- determine photosynthetic active radiation that passes the canopy and that is reflected by the ground
- measure snow depth at the ground
- observe the plant phenology,

and the implementation of measurement protocols that still need to be finalized and approved within ICOS.

The ECLAIRE project foresees two intensive measurement periods in 2013 (one in winter and one in summer) and in preparation for these campaigns the installation of a Fast Isoprene Sensor to measure Isoprene fluxes plus the use of the PTR-MS to measure VOC concentrations and maybe also fluxes is ongoing.

Summarizing, the installation of instruments at the brand new ABC-IS Forest Flux Station has progressed very well in 2012. Measurements have started in late spring and are going on very well. The timelines of data look generally very good with few missing data points due to instrument failure or maintenance. The equipping of the station to comply with ICOS ES Level 2 requirements is proceeding well and should be finalized in 2013.

Acknowledgement

The authors would like to thank the colleagues of the ABC-IS station running the meteorological instruments, gas phase analysers and data acquisition system. Their work enabled the authors to easily grab data from the 'EMEP site' and compare them to data from the tower top. In addition, we would like to thank also everybody who went with us through the hardship of climbing up the tower and installing instrumentations there during the hot summer season.

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