InGOS TNA 1-2 Activity Report

InGOS Measurements for Footprint Evaluation

Natascha Kljun, Department of Geography, Swansea University, UK

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Introduction and motivation

Footprint models are used to determine the area of influence to measurements. Knowledge of this area is essential for correct interpretation of tower measurements and for upscaling exercises, especially in the case of tall towers within heterogeneous landscapes (e.g., Vesala 2008). This fact has been acknowledged by the InGOS participants at the very early project/planning state. We have very recently improved an existing footprint model (based on Kljun et al. 2002, 2004) allowing it to include heterogeneous surfaces using surface characteristics derived from airborne LiDAR data.

In line with InGOS objectives, we use the footprint model as a tool for interpretation and allocation of sources and sinks for greenhouse gases measured at tall towers. So far, only sparse data are available for in-situ validation of footprint models. By classification and quantification of CH_4 and CO_2 surface fluxes within the footprint of tower-mounted instruments, we aim to develop a tool available to all InGOS tall tower sites. Further, the derived dataset will be available for comparison of several footprint models used by the InGOS team.

Scientific objectives

It is a set goal of InGOS to upscale and understand CH_4 sources/sinks from tall-tower measurements and it has been suggested to use footprint models for this exercise.

For this study, we have set up 100 additional soil chambers (or collars, respectively) at the Norunda site, to measure seasonal and spatial variability of CH_4 soil fluxes. The chambers have been installed along four transects of 750 m length and represent major surface vegetation/cover and soil characteristics at the Norunda site: mature forest, thinned forest, mix of mature and regrowth forest, and recently harvested areas.

The measured soil fluxes provide one of the very few in-situ validation datasets for footprint models. We will evaluate the footprint models of Kljun et al. (2002, 2004) using this dataset and tower measurements. Further, the data will allow for upscaling CH_4 fluxes for the Norunda site.

In addition to CH_4, we use CO_2 as tracer, as CO_2 flux measurement techniques (using eddy covariance systems) at tower level are already well established using the same modelling approach for CH_4 and CO_2. This is based on the assumption that even though fluxes, sources and sinks of CH_4 and CO_2 differ, the transport/dispersion of both greenhouse gases is comparable.

Reason for choosing station

The PI of this study, Natascha Kljun, conducted an airborne survey of the Norunda site in 2011 (UK NERC/ARSF funding), collecting high-resolution LiDAR and hyperspectral data of an area of 4 km x 4 km centered at the Norunda flux tower. Maps of digital elevation, tree height, canopy height, and leaf area index were derived on the basis of the LiDAR data. The combination of LiDAR and hyperspectral data allows for further discrimination of deciduous and coniferous trees.

CH_4 gradient and CO_2 flux measurements at several levels at the tall tower of Norunda, together with existing scattered soil chamber data for CH_4/CO_2, provided an ideal set up for our experiment.

Method and experimental set-up

(1) Soil chambers were set up along four transects of 750 m length, each transect with 25 collars, totaling 100 collars within 3000 m, all situated within the main footprint of the tower (see Figure 1). The collars represent the major surface vegetation/cover at the Norunda site: mature forest, thinned forest, and recently harvested areas.

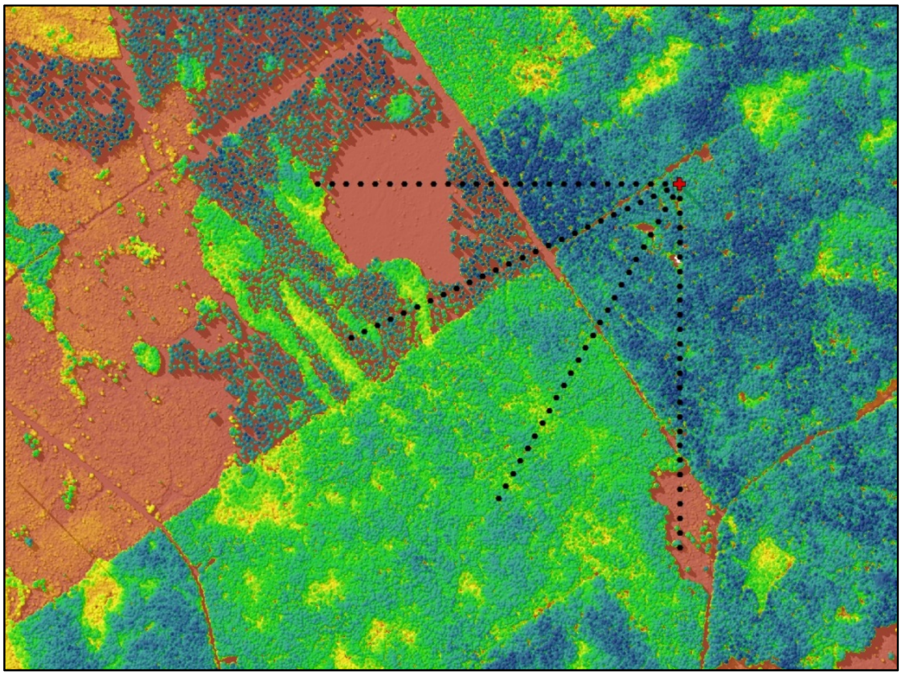

Figure 1: Location of collars for chamber measurements of CH_4 and CO_2 (black dots, each transect covers a distance of 750 m). The tower location is depicted by the red cross. The background map is tree height from LiDAR measurements, for illustration.

(2) Manual soil chamber measurements have been collected throughout the growing season (one campaign per month since start of the project) to allow analysis of seasonal variability. These measurements have been undertaken by site-affiliated ICOS technicians and by the PI. We used a Los Gatos Research ultraportable greenhouse gas analyser (CH_4 / CO_2 / H_2O) and an EGM-4 environmental gas analyser (CO_2, PP Systems). In addition, soil temperature (STP-1, PP Systems) and soil moisture (HH2, Delta-T Devices Ltd) has been measured at each collar coincident with the chamber measurements. It is planned to run at least one more measurement

campaign before the end of the growing season, within the next few days (end of September), and possibly a few comparison measurements in spring 2015.

(3) A footprint climatology has been derived based on turbulence input from the flux tower and on surface input (roughness, canopy height) from the LiDAR data.

(4) The soil flux data, together with tall tower measurements, will be used to validate the footprint tool.

(5) Finally, an upscaling exercise will make use of all collected data: allocation of CH_4 and CO_2 chamber measurements to surface/vegetation types and upscaling using footprint climatology and CH_4 concentration and CO_2 concentration and flux data from the Norunda tall tower.

Preliminary results and conclusions

The soil fluxes measured at the site show very high spatial variability, for both CH_4 and CO_2 fluxes. In general, negative fluxes (uptake) have been observed for CH_4, while for CO_2, these are positive fluxes (note: we used a dark chamber, hence measured soil respiration). CH_4 uptake of up to -22.98 µmol $m^{-2}h^{-1}$ was observed, with a median for all chambers and observations of -2.99 µmol m^{-2} h^{-1}. The dry summer this year (i.e. dry soils and high soil temperatures) clearly promoted CH_4 uptake. Positive CH_4 fluxes were measured at flooded collar locations and fully saturated soils. CO_2 soil fluxes varied with soil temperature and location (mature forest vs thinned forest vs clear cut) and were between 0 and 11.21 µmol m^{-2} s^{-1}, with a median of 2.59 µmol m^{-2} s^{-1}.

We have further derived footprint climatologies for several tower heights (cf. Figure 2) and seasons for evaluation of the footprint models and the upscaling exercise.

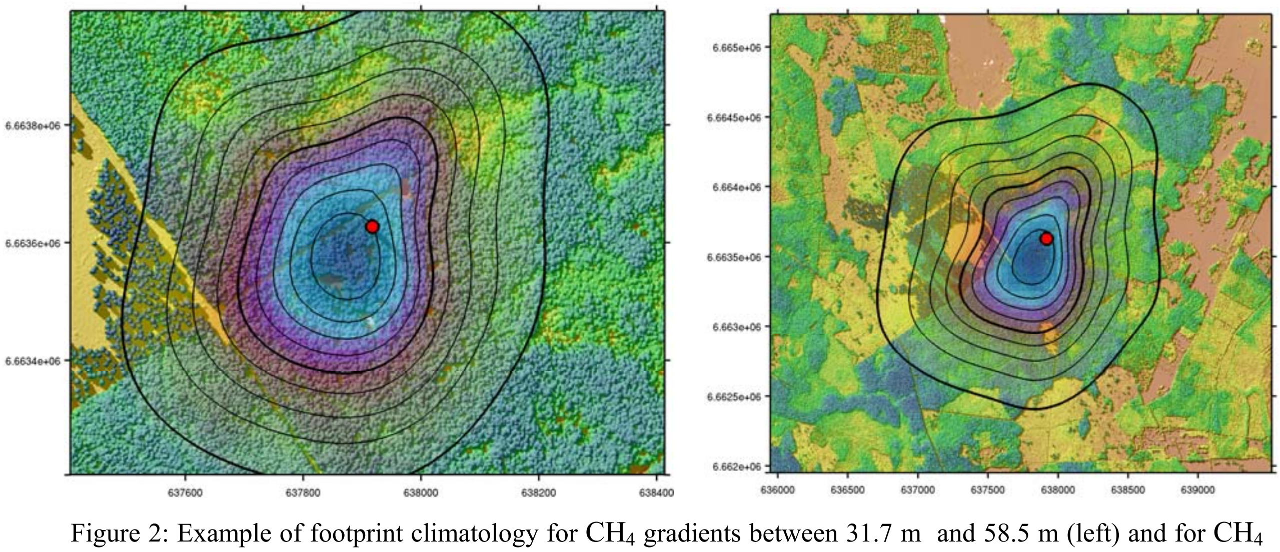

Figure 2: Example of footprint climatology for CH_4 gradients between 31.7 m and 58.5 m (left) and for CH_4 gradients between 31.7 m and 100.6 m (right). Contours are plotted for each 10% of the footprint. The tower location is depicted by the red dot. The background maps are tree height from LiDAR measurements, for illustration. Coordinates are in UTM.

Outcome and future studies

(1) The dataset of CH_4 and CO_2 soil fluxes is currently being used for evaluation of a footprint model which will be available to all InGOS tall-tower sites. The model will be capable of processing long-time series of data, i.e. high temporal resolution for several years of data.

(2) The above dataset will further provide essential for our upscaling exercise at the Norunda tall tower site. We currently are working on the first manuscript using these data: Sundqvist E., A. Persson, N. Kljun, P. Vestin, A. Lindroth: 'Upscaling of soil methane exchange in a boreal forest using chamber measurements and high-resolution LiDAR elevation data'.

References

Kljun, N., P. Calanca, M.W. Rotach, H.P. Schmid, 2004: A Simple Parameterisation for Flux Footprint Predictions. Boundary-Layer Meteorology 112, 503-523.

Kljun, N., M.W. Rotach, H.P. Schmid, 2002: A 3D Backward Lagrangian Footprint Model for a Wide Range of Boundary Layer Stratifications. Boundary-Layer Meteorology 103, 205-226.

Vesala, T., N. Kljun, Ü. Rannik, J. Rinne, A. Sogachev, T. Markkanen, K. Sabelfeld, Th. Foken, M.Y. Leclerc, 2008: Flux and Concentration Footprint Modelling: State of the Art.