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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Overview of a prescribed burning experiment within a boreal forest in Finland" *by* A. Virkkula et al.

Anonymous Referee #2

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GENERAL COMMENTS

The stated purpose of this article is to provide an overview of a prescribed burning experiment within a boreal forest by describing the experiment preparations and measurements and assessing the performance of the experimental setup for studying wildfires.

The goal of the experiment was "to collect data for estimating the effect of natural forest fires on air quality and climate". The experiment objectives included 1) obtain emission factors of aerosols and gases, 2) characterization of climatically relevant physical properties of smoke aerosol, 3) quantify the connections between ground-based smoke observations and satellite remote sensing, 4) obtain data for testing & improving mod-

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eling of atmospheric dispersion of smoke plumes, 5) study the post-burn recovery of the forest and 6) quantify the changes soil carbon stocks and greenhouse gas fluxes. I have serious reservations regarding the experiment overviewed in this paper. The experiment goal was "to collect data for estimating the effect of natural forest fires on air quality and climate". However, the experiment studied the prescribed burning of logging slash from a small scale (< 1 ha) clear-cut. The study site is not a reasonable proxy for natural forest fires.

In addition to the site not being a reasonable proxy for a natural wildfire, the experiment was poorly designed/set-up to accomplish the objectives. The small unit didn't produce a wide plume. The concentrated fuel load and low wind speeds would result in a vigorous, upright plume that would likely inject the bulk of the smoke well above the downwind sampling locations, even the 76 m tower. The gas instrumentation at the SMEAR II mast doesn't seem to have the proper temporal resolution (30 sec response, 1-minute averages) to measure smoke under conditions of this burn and the precision is not reported and may insufficient for the weak enhancements above background (especially CO).

To be publishable, I believe the authors need to revise the paper by: 1) focusing on the successful measurements and discussing these in the context of previous studies. The paper needs an improved comparison of the VOC and particle measurements with previous studies, including correction of errors in Section 3.4 (see below), 2) identify a few findings that are new or confirm previous studies and summarize the importance of these findings with respect to air quality or climate, and 3) provide an expanded and improved description of what was learned from this experiment and how a future experiment would be conducted to successfully accomplishment the stated goals (e.g. studying a fire that is an appropriate proxy for a natural wildfire). The authors mention mobile platforms but should elaborate further, e.g. discussing instrument payloads and measurements requirements (response time, precision, what species to measure).

SPECIFIC COMMENTS P3, L3: Grell et al. 2011good reference linking fires to

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weather, but should replace Andreae 1991 and Penner et al. with more recent and more relevant references to support this statement, including the addition of a reference related to health effects.

P3, L7-9: Is transport from Europe to the Arctic important?

P3, L9-11: The description of fire emission impacts on climate should be improved. Consider differentiating between short-term (aerosol, ozone, ch4) climate forcers and long-term climate forcers (co2, n2o) and consider using positive / negative radiative forcing rather than warming/cooling. See Shindell et al. (2009) for examples (Shindell et al. (2009) Science, 326, 716-718).

P3, L12: Reference(s) needed

P3, L17-19: van der Werf et al. is emission inventory, should cite Giglio et al. (2010) instead (Giglio et al. (2010) Biogeosciences, 7, 1171-1186).

P3, L 19-20: Not true. Satellite images provide information on burned area and fuels involved, they do not provide information on the amount of fuel consumed or smoke emitted. Emission inventories provide this information, e.g. van der Werf et al. (2010).

P3, L27: "satellite estimates" of what?

P4, L12: Is the experiment approach being assessed for use with wildfires or large managed burns?

P4, L16-24: The wind is from the preferred direction only 10% of the time? Could a more favorable month have been used (July or August)? Section 2.3.1: The authors should include a relevant estimate of the measurement precision for the CO2 and CO instruments at the SMEAR II tower, e.g. the 30-s standard deviation while sampling a mid-range calibration gas. These are key measurements and it seems like the enhancements in the diffuse smoke may not have exceeded the measurement precision very often. Please clarify. Also, the data is described as a 1 minute time step, but this appears to include 30-s flush time as the sampling rotates between levels. Please

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clarify, are the concentration data 30-second averages?

P7, L9: what is the height above ground level of the inlet at REA cottage?

P8, L31-32: Dust Tracks measure light scattering. Were these calibrated for aerosol from biomass burning?

P10, L8-18: Please specify: 1) what period were the bi-weekly measurements taken, over the entire year, over the growing season, over the summer, etc. and 2) was temperature (or other variables) used to interpolate CO2 effluxes over hours of day and between days daily as soil temperature and/or soil moisture

P10, L20-22: Please specify what time of year the VOC soil efflux measurements taken?

P11, L4-6: It should be noted that MCE provides a measure of the relative mix of flaming and smoldering combustion with MCE approaching 1 for pure flaming combustion.

P11, L 19: Provide reference(s) for statement that single-scattering albedo = 0.3+/- 0.1 for 'BC'.

P14, L18-29: There can only be one fire-front passage, however this section refers to multiple fire-front passages. The heat flux measured at the surface (Q) that is plotted in Figure 3b shows the fire-front passage between 8:30 and 9:00. The first spike in sensible heat flux, which occurred just after 8:00, was a result of the plume passing across the instrumented 12 m pole.

Section 3.2 Figure 2 should cover only region of interest, 6:00 to 15:00, this would make it much easier to read. The gas instrumentation at the SMEAR II mast doesn't seem to have the proper temporal resolution (30 sec response) to measure smoke under conditions of this burn and the precision is not reported and may insufficient for the weak enhancements above background (especially CO). Please provide an estimate of the measurement precision for CO and CO2 relevant for the 1-minute time resolution reported, e.g. 30-s standard deviation of measured mixing ratio while sam-

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pling a midrange calibration gas. The background was calculated “as the running first percentile of the one-minute averages during the 30 minutes before and after each measurement”. This description is unclear.

Section 2.3.1 states the gases were measured at 6 heights with a 1-minute time step - 30 second measurement and a 30 second flush time between levels, so there are 5 measurements per level each 30 minutes. Did you use the lowest of the 5 measurements as the background? Did you use the CO to identify the background time period or did you select for each gas separately? In panel F) of Figure 2 it is clear the CO2 background is changing. Please comment on: the source of this change, the rate of change during the burn, and if / how was accounted for in calculating CO2 background. I’m guessing the changing CO2 results from the growth boundary layer, initially shallow and having high CO2 from nocturnal ecosystem respiration, as it entrains air from above the canopy.

P16, L 24-25: There are 100’s of organic gases produced in incomplete combustion (see Yokelson et al., 2013; Akagi et al., 2011), the relative importance of these gases is not fully understood and likely varies with ambient conditions (e.g. Crounse et al., Atmos. Chem. Phys., 9, 4929-4944, 2009).

P16, L33: What is the CO 30-sec measurement precision? Better than 40 ppb ?

P16, L32 – P 17, L23: I would recommend removing this section and Figure 5. It seems that the SMEAR tower did not receive enough exposure to the smoke plume to support this analysis. In fresh biomass smoke correlations between deltaCO and deltaCO2 should be very high. The lack of a strong correlation indicates the measurements are unreliable for such an analysis. I suspect the diffuse and spotty smoke, vary CO2 background, insufficient measurement precision, and sample times that were to large relative to smoke exposure all played a role in the inconclusive results.

P16, L25-29: I recommend focusing on only the time period before and during the fire 6:00 to 15:00. This would also improve the readability of Figure 2.

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Section 3.3 Aerosol at SMEAR II: The authors should compare their results with previous studies, e.g. Hobbs et al. (1996) – similar fire type (slash from clear-cut), particle measurements for comparison (Hobbs, P. V., J. S. Reid, J. A. Herring, J. D. Nance, R. E. Weiss, J. L. Ross, D. A. Hegg, R. D. Ottmar and C. Liousse (1996) "Particle and Trace Gas Measurements in the Smoke from Prescribed Burns of Forest Products in the Pacific Northwest." In Biomass Burning and Global Change, J. S. Levine Ed., MIT Press, Cambridge, MA, 697-715.) And also with the reviews of Reid et al. (2005) (Atmos. Chem. Phys., 5, 799-825; Atmos. Chem. Phys., 5, 827-849)

P18, L6: specify if this (3.4 ug/m3) is the BC concentration.

P20, L28-30: This interpretation is incorrect. BC production is associated with flaming combustion not smoldering combustion. One would expect to see high BC during flaming combustion but little during smoldering combustion. This is easily observed in the field: torching conifer tree crowns produce smoke that is visually very black while post fire front smoldering combustion produces smoke that is white in color. These common qualitative observations have been quantified in numerous laboratory studies (McMeeking et al. (2009) Volume 114, Issue D19; Hosseini et al. (2013) J. Geophysical Research – Atmospheres, Volume 118, Issue 17, 9914 – 9929).

P21, L33: Please note the height of the REA cottage inlet

P21, L34: Why were data not available after 12:00?

P22, L8 – 22: The correlation of deltaX with deltaCO seem reasonable for fresh smoke this suggest the poor correlation between deltaCO and deltaCO2 was related to the CO2 measurement. Emission Ratios When emission ratios (ER) are used to calculate EF the intercepts are usually forced to zero (e.g. Yokelson et al., 1999; Burling et al., 2010). Therefore one should use the forced zero intercept slopes for comparison with published values literature values and given in Table 3 instead of the slopes with the fit intercept. The authors made an error in calculating emission ratios from emission factors. They did not account for the molecular weights of the species. The calculation

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should be made as: deltaX/deltaCO = (MWCO/MWX) × (EFX/EFCO) e.g. for toluene: MWtoluene = 92 g/mol and A & M EFtoluene = 0.40 g/kg MWco = 28 g/mol and A & M EFco = 107 g/kg deltatoluene/deltaCO = (28/92)×(0.40/107) = 0.00114 See Sect 2.2 of Andreae & Merlet 2001. The more recent EF review by Akagi et al. should be used as the basis for comparison, not A & M 2001, it is outdated. The authors should also include Simpson et al (2011) who measured boreal fire emissions.

P24, L 4-11: Please note the measurement response time, typical aircraft speed, and the typical sample length of each plume passage maximum (e.g. at 100 m/s speed and 1 sec measurement rate, each data point is roughly a 100 m sample segment).

P 25, L26-27: Please give examples/reference for this statement.

P 25, L 26-30: Can the authors comment on the magnitude of soil VOC emissions relative to foliar emissions and emissions from down dead wood?

P27, L 10-12: After correcting calculation errors please compare with more relevant/recent papers (Akagi et al., Simpson et al., 2011 – see above)

P27, L14-32: Consider comparing with Hobbs et al. (1996) and Reid et al. reviews (see comments above)

Specific comments on Figures

Figure 2: Focus on time period before and during the burn 6:00 to 15:00. Specify the temporal spacing of data points at each level (6 minutes?).

Figure 3. P14, L 31 states the TKE and Hs are 1 minute averages. Please clarify in caption.

Figure 4. The water vapor mixing ratio should be rescaled

Figure 5. This figure should be eliminated. See comments above.

Figure 6. Focus on time period before and during the burn 6:00 to 15:00. L6 change

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‘E)’ to ‘F)’, specify where the mass concentration of particles <10um comes from (Dust Track?)

Figure 10. Focus on the 7:00 to 10:00 period since VOC measurements after this period are not discussed in the paper.

Figure 13. Is the concentration in panel B average, median, or peak? Caption for panel A, should this read ‘symbol color’ ?

TECHNICAL COMMENTS

P3, L12: change ‘have also’ to ‘also have’

P3, L30-31: Awkward sentence should be rewritten.

P3, L34: change ‘wildlife’ to ‘wildfire’

P4, L2: change ‘burning forests’ to ‘managed forest burning’

P4, L11: sentence starting with ‘Nowadays’ is awkward and be rewritten

P4, L 14: suggest using ‘managed burning’ instead of ‘controlled’

P4, L15: delete ‘controlled’

P4, L34: Maybe change to ‘Specific goals and objectives. . .’ since the list includes both goals and objectives (i.e. clear and measurable targets such as measuring emission factors)

P4, L12: change ‘analyze’ to ‘assess’ or ‘evaluate’ and delete ‘used’

P4, L24: ‘frequently’, need better description – is this 3 m/s average or median or what? Insert ‘threshold’ prior to ‘required’

P5, L6: change ‘an extraction’ to ‘the difference’

P5, L14: change ‘an extraction’ to ‘the difference’

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P9, L28: “have a lack-time” doesn’t make sense, please rewrite.

P10, L6: change ‘burning’ to ‘burn’

P14, L32: delete ‘and’ between ‘fluxes’ and ‘associated’

P16, L27: change ‘08.47’ to ’08:47’

P 25, L12: awkward, needs to be rewritten

Interactive comment on Atmos. Chem. Phys. Discuss., 13, 21703, 2013.