Interactive comment on "Airborne and ground-based measurements of the trace gases and particles emitted by prescribed fires in the United States" *by* I. R. Burling et al.

Response to Anonymous Referee #1

We thank the referee for the positive comments and the suggestion to publish without further revisions.

Response to Referee #2 (G. Rein)

We thank the referee (G. Rein) for his comments. We address his comments below:

The referee points out that "Error bars in the field are larger. The paper is experimental, but does not report any experimental error or measurement uncertainty."

It is true that the emission factors and the uncertainty in the emission factors can vary from fire-to-fire and within the fire. Our approach was not to focus on the individual fires, but to estimate the mean EF for fires of a vegetation class or type. We reported the mean and standard deviation for each vegetation class. We believe it is this mean and standard deviation for the groupings that are of greater value to modelers and others who would use these data, as they better represent the variability in emission factors for the various vegetation classes.

However, to acknowledge the referee's important point we have added some explanation regarding the variability in the individual fires in Sect. 2.6 (Emission ratio and emission factor calculations). The corresponding paragraph in Sect. 2.6 will be edited as follows (additional text in bold):

"For chemical species quantified from the analysis of single-beam spectra, excess mixing ratios above background (denoted as ΔX for any species "X") were calculated for each FTIR grab sample by subtraction of background values for those species. The transmission spectra intrinsically use ambient air as the background reference spectrum, so the mixing ratios calculated from fitting of these spectra are already excess values. Since we collected grab samples of the fresh smoke for nearly the entire duration of the fire, fire-average molar emission ratios (ER) were determined from the linear fit of a plot of ΔX vs. ΔY (where Y is often CO or

CO_2) for each fire with the intercept forced to zero (Yokelson et al., 1999). ***For those compounds that were measured with high signal-to-noise (e.g. CO, CO_2, CH_3OH, …) the standard deviation in the slope reflects the natural variation in ER (and subsequently EF) over the course of the fire. For these compounds the variability in the airborne samples was typically <10%. For those compounds measured with low signal-to-noise (e.g. glycolaldehyde, phenol) or for those fires where we obtained a limited number of grab samples from the aircraft (Bear Pen, Holly Shelter, Atmore, and Shaver) the uncertainty is significantly larger than the natural variability.***"

As the referee also pointed out there is potential uncertainty in the value for the carbon mass fraction of the fuels since these were not measured directly. Our original wording was as follows:

"We assumed a carbon mass fraction (F_c) of 50% for the fuels burned here, an estimate based on the comprehensive work of Susott et al. (1996) and on measurements of similar fuel types (Burling et al., 2010; Ebeling and Jenkins, 1985)."

The following will be added immediately after to better clarify the uncertainty in the carbon mass fraction:

"**The actual fuel carbon percentage likely varied from this by less than a few percent. For the similar fuel types investigated by Burling et al. (2010), the percentages ranged from 48 to 55% carbon by mass. Emission factors scale linearly with the assumed fuel carbon fraction.**"

The referee suggests: "The larger errors/uncertainties in the measurements is one of the most important disadvantages of field work because conditions are more difficult to control."

We respectfully disagree with portions of this statement. We believe that probing the natural variability from real fires in the field can be much more informative than laboratory experiments as these are real fires in a natural environment, which can burn under various conditions. And while fires in the laboratory can have smaller uncertainty or variability by the ability to control conditions, it's not always clear how well data from laboratory burns represents actual, field fires particularly when measuring emissions associated with live fuels.

That is to say, we believe the overall variability in a group of fires in a particular fuel category is of more value than the intrafire variability from sample-to-sample.

To address the referee's comment regarding the residual smoldering of organic soils, we will mention this in the introduction as follows (new text in bold):

"Prolonged smoldering after local convection from the flame front has ceased is often termed "residual smoldering combustion" (RSC, Bertschi et al., 2003) and is responsible for many of the negative air quality impacts of prescribed burning (e.g. smoke exposure complaints, visibility-limited highway accidents (Achtemeier, 2006)) on a local scale. Ground-based systems are usually required for measurements of RSC smoke emissions. The emissions from RSC burning are quite different from those of flaming combustion due to the lower combustion efficiency. The strategies adopted by land managers for prescribed burning typically minimize the amount of RSC and its impacts on local populations. In contrast, wildfires normally burn when "fire danger" is at high levels and forest floor moisture is at a minimum (Deeming et al., 1978), often resulting in significant amounts of RSC. There are usually few or no options for reducing smoke impacts on populated areas from wildfires. ***Although not a factor in this study, in some wildfires, organic soils (peat) may also burn contributing to RSC.*** *Residual smoldering combustion can continue for weeks after initial ignition and can account for a large portion of the total biomass consumed in a fire (Bertschi et al., 2003;* ***Rein et al. 2009****). Naeher et al. (2006) measured* $PM_{2.5}$ *and CO from prescribed fires from sites in South Carolina with large amounts of down, dead fuel to investigate the effects of preburn mechanical mastication. We are unaware of any other peer-reviewed field measurements of the emissions from RSC in the temperate regions of the US."*

Added reference:

Rein, G., Cohen, S. and Simeoni, A.: Carbon emissions from smouldering peat in shallow and strong fronts, Proceedings of the Combustion Institute, 32, 2489-2496, doi:10.1016/j.proci.2008.07.008, 2009.