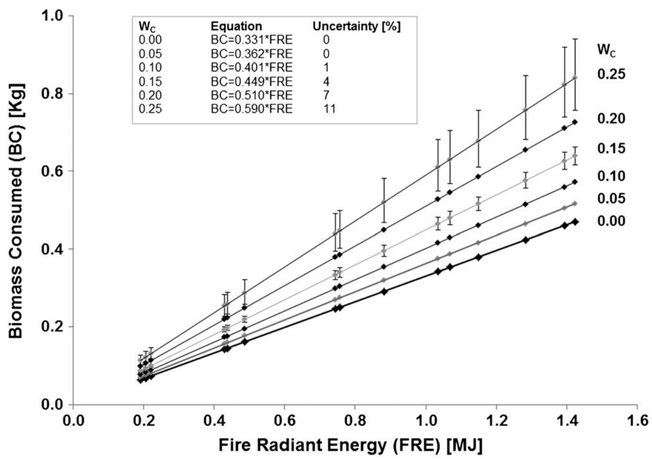

Figure 3. Impact of fuel water content, W_C (dimensionless), on the relationship between retrieved FRE and biomass consumed (BC). Equation (8) is theoretically demonstrated for W_C values from 0 to 0.25 for the 15 dry pine fuel FRE retrievals illustrated in Figure 1, and the resulting linear equations are plotted as diagonal lines. The % uncertainty is calculated for each W_C line by applying the 95% confidence intervals from the gradient and intercept coefficients in (8). Only the error bars associated with 0.15 and 0.25 are shown for illustrative purposes. Pine needles do not burn if the water content is higher than ~0.26. The reported equations values are derived from the current experimental data and are in close correspondence to the theoretical values that can be derived from (5).

mean difference between the theoretical and observed values across the range of W_C was 0.13 with a standard deviation of 0.09 MJ kg^{-1}. This difference is likely due to errors in the parameterization of (4), for example, the heat of desorption is not particularly well defined in the literature, or due to an additional unaccounted for processes such as the absorption of emitted energy by water vapor and smoke in the atmospheric column [*Brown and Davis*, 1973; *Freeborn et al.*, 2008].

[15] The 24 measured W_C, BC, and retrieved FRE values were used to estimate the terms b and m in (6) by linear regression to provide $b = 3.025$ (MJ kg^{-1}) and $m = 5.32$ with 95% confidence intervals ±0.079 and ±1.05, respectively. This provides

$$\mathrm{BC} = (3.025 - 5.32 {*} W_C)^{-1} {*} \mathrm{FRE}, \tag{8}$$

where BC (kg) is the total biomass consumed and FRE (MJ) is the fire radiative energy. Equation (8) enables the estimation of biomass consumed from FRE explicitly taking into account fuel water content and updates the conventional biomass consumed FRE relationship described by *Wooster et al.* [2005] and (7).

[16] Figure 3 shows the results of the application of (8) for water content ranging from 0 to 0.25 applied to the 15 dry fuel FRE values illustrated in Figure 1. Clearly, changes in fuel moisture will bias conventional biomass burning estimates from FRE (7). It should be noted that while pine needles do not combust at $W_C \sim 0.26$, peat and other fuels can combust at significantly higher moisture contents [*Benscoter et al.*, 2011], potentially making the impact of fuel water content on FRE biomass burned retrieval even more pronounced for these fuel types. Comparison of (8) and (7), which was parameterized at $W_C \sim 0.12$, yields a 14% difference in the gradient. This difference can be partly attributed to the variations in the heat of combustion, time from W_C calculation to combustion, and the different FRP retrieval methods [*Wooster et al.*, 2003, 2005].

4. Conclusions

[17] This research confirms past studies showing strong linear relationships between biomass consumed and integrated fire radiant energy. Measurements from two sets of experimental burns were used to quantify the impact of fuel water content on fire radiant energy, and to derive a new formula where the linear relationship between biomass consumed and fire radiant energy is parameterized for fuel water content. Comparison of these results to past studies demonstrates that dual-band thermometry produces data of comparable accuracy and precision to other FRP retrieval approaches. The results of this study have several implications for the future use of satellite based fire energy retrievals to estimate biomass consumed. Conventional biomass burning retrievals, using the equation proposed by *Wooster et al.* [2005], do not take into account fuel moisture and may systematically bias estimates of the biomass consumed. This is particularly relevant given that the fuel moisture may change through the fire season, and the seasonality of fire extent and intensity remains an area of active research [*Korontzi et al.*, 2004; *Roy et al.*, 2005; *Yates et al.*, 2008; *Archibald et al.*, 2010; *Meyer et al.*, 2012; *Randerson et al.*, 2012].

[18] This study suggests the need to test whether similar moisture content relationships are observed for diverse fuels such as in peat, woody debris, and leaf litter [*Hyde et al.*, 2011; *Kremens et al.*, 2012; *Brewer et al.*, 2013]. Moisture-corrected FRE biomass burned equations would improve the application of spaceborne fire radiant energy products in assessing biomass burning but this application will require spatially and temporally explicit estimation of fuel moisture. Future research to further validate the methodology is recommended. This should include cross-comparison of single band and dual-band FRP approaches to further evaluate moisture effects on FRP [*Wooster et al.*, 2005] and the application of the method to satellite FRP data and fuel stratification maps to determine fuel-type specific coefficients for (6); thus, enabling systematic moisture content corrections for FRE to be realized.

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