A Consistent Set of Biomass Burning Terminology

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An incomplete selection of concepts and definitions with an emphasis on emissions estimates. We didn't invent these terms, we just think they make sense. In case of a conflict between definitions we recommend:

1. the terms we have defined below
2. the definition which is obviously more precise
3. at least provide the definition of the term as you intend it to be used.

Terms relating to the fuel

Biomass
Mainly plant material, live (phytomass) or dead (necromass).

Aboveground biomass
The litter layer and everything above it. Litter is fallen, still-identifiable biomass such as leaves or twigs.

Belowground biomass
Biomass below the litter layer, e.g. duff (partially decomposed organic matter, not identifiable and usually more dense than litter), peat, organic soils, roots, etc.

Fuel
That part of the biomass that normally burns under specified fire conditions. Fuel is often further classified by the time-scale it takes to approach equilibrium with a fixed relative humidity.

Fuel Moisture
Most commonly defined as: (wet weight-dry weight)/dry weight.

Biofuel
This term has been used most often to denote biomass that is used as a (renewable) domestic or industrial energy source (cooking, heating, lighting, etc.) instead of fossil fuels. It may confuse people to use "biofuel" as a term equivalent to biomass.

Biomass/fuel loading
Usually the mass of biomass/fuel per unit area on a dry weight basis.

Loading probably makes more sense than "density", which is sometimes used.

Combustion Factor or Combustion Completeness
The fraction of biomass exposed to a fire that was actually consumed (or volatilized) in a fire. Combustion Efficiency has a different , long-standing meaning explained below.

Fuel consumption
A direct measurement of how much biomass was consumed or volatilized in a fire, usually expressed as a mass per unit area (on a dry basis). Biomass loading x combustion factor is one way to estimate fuel consumption. Another way is to average the relevant fuel consumption measurements.

Burned area
Usually the area within the perimeter of a fire.

Unburned area
Often an unburned island within a burned area or "burn scar".

Terms relating to the the fire itself and the initial emissions

Emission Factor
(EF) grams compound emitted per kg of fuel burned (on a dry mass basis). EF x fuel consumption x burned area is the total emissions of a compound from a burned area.

Emission Ratio
(ER) dimensionless molar ratio between two emitted compounds measured at the fire. Most often reported as $\Delta X/\Delta Y$ where "ΔX" and "ΔY" refer to excess mixing ratios (defined as the mixing ratio of a species in the smoke minus the mixing ratio of that species in the background air) and "Y" is usually CO or CO_2.

Flaming Combustion
The luminous, rapid reaction of O_2 with gases evolved from the solid biomass fuel. The gases are evolved because of the heat from the flames (or glowing, vide infra). Dry, small-diameter aboveground biomass tends to burn mostly by flaming.

Smoldering Combustion
A combination of surface oxidation (or gasification, commonly known as

"glowing") and pyrolysis (mostly the thermal breakdown of solid fuel into gases), with a little bit of distillation mixed in. Large-diameter aboveground biomass and belowground biomass tend to burn mostly by smoldering. Smoldering and flaming often occur simultaneously during a fire and combustion "phases" often do not exist. For more on combustion processes and chemistry see Yokelson et al (1996, 1997) or Bertschi et al. (2002) .

Oxygen Deficient Combustion

A common problem in closed industrial reactors. Almost impossible in open fires, but frequently invoked in the fire literature anyway.

Combustion Efficiency

Defined as the fraction of fuel carbon converted to carbon as CO2. Historically, combustion engineers want the CE of their reactors to be 1 to maximize energy delivered by the fuel.

Modified Combustion Efficiency

defined as $\Delta CO2/(\Delta CO2+\Delta CO)$ and abbreviated as MCE. Related to CE, but easier to measure in the real world. Has the further advantage that other carbonaceous compounds can be plotted vs MCE as independent variables. Pure flaming usually has MCE of 0.97-0.99 and pure smoldering usually has MCE of 0.75-0.85. CE and MCE are higher when the ratio of flaming to smoldering combustion is higher.

Fire Intensity

Most often reported in the fire literature as "fireline intensity" or energy released per unit time and fire perimeter (kilowatts/meter or equivalent). The most intense fires do not always have high MCE.

Fire Severity

Describes the downward heat flux and the impacts on the ecosystem (primarily soil).

Terms relating to downwind, post-emission smoke

Normalized Excess Mixing Ratio

(EMR) $\Delta X/\Delta Y$ where Y is a useful smoke tracer such as CO. This quantity has the same units as Emission Ratio. The term Emission Ratio should be reserved for measurements of the emissions at the source! The normalized excess mixing ratio can be measured anywhere in the plume, including downwind. The normalized excess mixing ratio is expected to be highly variable for reactive compounds downwind from fires and

dependent on the details of the post-emission processing. Thus, a normalized excess mixing ratio (for a reactive compound) measured downwind may not be equal to the emission ratio, even though it is expressed in similar fashion. For instance, ΔO3/ΔCO is a negative quantity in nascent smoke, but may rapidly increase after emission if photochemical processing occurs.

Enhancement Factor

Another term for "normalized excess mixing ratio". It is shorter, but we prefer the latter, because species are not always enhanced in downwind smoke; sometimes they are depleted.

Export Factor/Ratio

Sometimes downwind measurements are reported as emission factors or emission ratios. This leads to confusion because values are obtained for reactive species that are different from the source values and the downwind values tend to be different every time. Perhaps it is better to call these downwind quantities, which are useful for estimating export from a region, for a highly specific set of circumstances , "Export Factor/Ratios"?

On Specifying Smoke Age

The literature is full of "unitless" adjectives for smoke age (fresh, young, moderately aged, aged, old, etc.). We have used the term nascent (defined as "in the act of being born"). The problem is that many of these terms have a differnet meaning for different authors. For instance, one author calls smoke 200m above the flames "fresh smoke" and another calls smoke 100km off the coast of Africa "fresh smoke". In the first case the smoke is <5 minutes old and in the second it may be 10 days old and thoroughly transformed from its initial state. To reduce confusion, it would be preferable for all authors to assign an age (or probable range in age) for their samples in minutes, hours, days, etc.

Additional sources for fire terminology as used by the forestry community

* Global Fire Management Center
* National Wildfire Coordinating Group

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