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A novel parameterization for wildfire plumes in LPJ-GUESS

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Wildfires are one of the major disturbances in the global terrestrial ecosystems and can be the key driver for both vegetation composition and structure, affecting the carbon stocks above and below the surface. With a total of about 2 Pg(C)/year emitted into the atmosphere wildfires also play an important role in the global carbon cycle. Beyond this, emissions from wildfires influence regional air quality, can have a fertilizing effect on the surroundings, or alter the albedo of both the burned area itself but also of distant areas when e.g. black carbon is deposited on ice sheets or snow. Large fires creating pyrocumulonimbus-clouds even elevate trace gases into the lower stratosphere.

The chemical and physical evolution of the compounds emitted by wildfires can be simulated by modern CTMs (Chemistry Transport Models) and ESMs (Earth-System Models). A key uncertainty in these models, though, are the fires and the resulting emissions themselves, both in space and amount. Many plume rise models use satellite retrievals for fire intensity as e.g. FRP (Fire Radiative Power) and top height for hindcast or historical simulations, where the accuracy of FRP is anti-correlated with the total emissions because the plume itself blocks the frequencies needed to measure a fire's intensity, i.e. the larger in scale a fire is the less accurate its intensity, and therefore, it is difficult to generate a vertical emission profile. Furthermore, for future projections, these parameters need to be computed from available information within the operating model.

The approach presented here was developed in the framework of the project CoBACCA and is an attempt to invert this problem. Therefore, we use the 2nd generation dynamic global vegetation model LPJ-GUESS and its incorporated wildfire-model SIMFIRE-BLAZE. Vegetation in LPJ-GUESS is represented by 12 different Plant Functional Types (PFTs; 10 tree and 2 grass PFTs) plus litter and soil pools. In combination with meteorological parameters, the combustion model BLAZE then computes their mortality, their combustion completeness, the intensity of the fire, and finally a vertical emission profile.

Another critical issue for the use of vertical emissions is that one of the uncertainties in atmospheric models is the height of the planetary boundary layer (PBL) which more or less determines whether emitted air-parcels remain in the mixing layer or reach the free troposphere or even the lower stratosphere. We, therefore, decided to compute the vertical emission profile relative to a model-generated PBL.

These emission profiles will be used online in the upcoming version 4 of the ESM EC-Earth but they can also be used offline as emission inventories for other models. This is a step towards a fully coupled plume-rise sub-grid model to be developed within EC-Earth4.