Supporting Information for ”A global bottom-up approach to estimate fuel consumed by fires using above ground biomass observations”

F. Di Giuseppe\textsuperscript{1}, A. Benedetti\textsuperscript{1}, R.Coughlan\textsuperscript{1}, C.Vitolo\textsuperscript{1}, M.Vuckvic\textsuperscript{1}

\textsuperscript{1}European Centre for Medium-range Weather Forecast (ECMWF), Reading, UK

Contents of this file

1. S1: Description of IFS-COMPO experiment performed

2. Figure S1: Map of biomes

3. Figure S2: Map of fire occurrence per biome

4. Figure S3: Modified normalized mean bias (MNMB) for all AERONET stations

5. Figure S4: L-VOD vs AGB conversion relationships

6. Table S1: Fire emissions and IFS-COMPO experiment ID
S1: Description of the IFS-COMPO experiment performed

Aerosol optical depth predictions are provided by the IFS-COMPO system which is a configuration of the Integrated Forecast System, IFS developed at ECMWF with the extended capabilities of including atmospheric composition tracers in the transport model and in the analysis (Flemming et al., 2015). The IFS-COMPO system is used operationally to provide global forecasts of aerosols, reactive gases and greenhouse gases as well as boundary conditions for higher resolution regional models proving air quality forecasts over Europe. Data are freely available from the CAMS website. IFS-COMPO has been developed since the early 2000 (Hollingsworth et al., 2008) and is the modeling and assimilation system of the Copernicus Atmosphere Monitoring Service, CAMS (Rémy et al., 2019; Flentje et al., 2021). Aerosols load are modelled using the developments of Morcrette et al. (2009) and uses species: dust, sea salt, black carbon, organic carbon and sulfates. Recently nitrate and ammonium have been added.

Dust aerosols and sea salt are represented by size bins for all other troposphere aerosols (carbonaceous aerosols and sulfates), bulk parameterizations are used and emission sources are defined according to established inventories (Lamarque et al., 2010). The IFS-COMPO system also includes chemically reactive tracers such as ozone, carbon monoxide, NOx, formaldehyde as well as greenhouse gases to mention a few. Specifically, biomass burning emissions contributing to black carbon and organic matter loads are prescribed from the Global Fire Assimilation System (GFAS, (Kaiser et al., 2012; Di Giuseppe et al., 2017, 2018)).
Figure S1: Map of biomes.

Biome classification used in this study following van der Werf et al. (2006) with EFOS "extratropical forest with organic soil", EF "extra tropical forest", PEAT "peat", TF "tropical forest", AGOS "agriculture with organic soil", AG "agriculture", SAOS "savanna with organic soil", Sa "savanna"
Figure S2: Fire occurrence per biome

Statistics of fire occurrence (FO) per biome type as defined in figure S1. Data statistics are derived from 2016 using GFASv1.2 fire radiative power dataset which includes MODIS observations from both TERRA and AQUA platforms. The histogram width is proportional to the biome total land coverage.
Figure S3: Modified normalized mean bias (MNMB) for all AERONET stations

Modified normalized mean bias (MNMB) for all AERONET stations using FRP prediction with and without inflation factor and experiments using model 1 and 3. MNMB measures the distance between observation and forecast and is normalized to make it non-dimensionless. It varies between $-2$ and $+2$ and has an ideal value of zero for a perfect model (and perfect observations). Values near the two extremes values of $-2$ and $+2$ signal extreme under and over predictions. Differences are concentrated in Central and South Africa and and the Amazon where most of the fire activity took place in September 2016.
Figure S4: L-VOD vs AGB conversion relationships

L-VOD vs AGB conversion relationships as derived from the work of Rodríguez-Fernández et al. (2018) using the datasets from Saatchi et al. (2011); Baccini et al. (2012); Avitabile et al. (2016) to define a benchmark AGB. The red circles represent the logistic regression fit on the median of the AGB data and the shaded intervals the regressions between the 5th and 95th percentiles.
Table S1: Fire emissions and IFS-COMPO experiment ID

Fire emissions calculations as boundary conditions of IFS-COMPO experiment and the complete set of IFS-COMPO outputs are also available through the ECMWF MARS archive with the name convention reported in table S4. Given the size of the simulations, requests to access the data can be addressed to the corresponding author.
References

Avitabile, V., Herold, M., Heuvelink, G. B., Lewis, S. L., Phillips, O. L., Asner, G. P., . . . others (2016). An integrated pan-tropical biomass map using multiple reference datasets. *Global change biology*, 22(4), 1406–1420.

Baccini, A., Goetz, S., Walker, W., Laporte, N., Sun, M., Sulla-Menashe, D., . . . others (2012). Estimated carbon dioxide emissions from tropical deforestation improved by carbon-density maps. *Nature climate change*, 2(3), 182–185.

Di Giuseppe, F., Rémy, S., Pappenberger, F., & Wetterhall, F. (2017). Improving forecasts of biomass burning emissions with the fire weather index. *Journal of Applied Meteorology and Climatology*, 56(10), 2789–2799.

Di Giuseppe, F., Rémy, S., Pappenberger, F., & Wetterhall, F. (2018). Using the fire weather index (fwi) to improve the estimation of fire emissions from fire radiative power (frp) observations. *Atmospheric Chemistry and Physics*, 18(8), 5359–5370. Retrieved from https://www.atmos-chem-phys.net/18/5359/2018/ doi: 10.5194/acp-18-5359-2018

Flemming, J., Huijnen, V., Arteta, J., Bechtold, P., Beljaars, A., Blechschmidt, A.-M., . . . others (2015). Tropospheric chemistry in the integrated forecasting system of ecmwf. *Geoscientific model development*, 8(4), 975–1003.

Flentje, H., Mattis, I., Kipling, Z., Rémy, S., & Thomas, W. (2021). Evaluation of ecmwf ifs-aer (cams) operational forecasts during cycle 41r1–46r1 with calibrated ceilometer profiles over germany. *Geoscientific Model Development*, 14(3), 1721–1751.

Hollingsworth, A., Engelen, R., Textor, C., Benedetti, A., Boucher, O., Chevallier, F., . . . others (2016). . . .
... others (2008). Toward a monitoring and forecasting system for atmospheric composition: The gems project. *Bulletin of the American Meteorological Society*, 89(8), 1147–1164.

Kaiser, J., Heil, A., Andreae, M., Benedetti, A., Chubarova, N., Jones, L., ... others (2012). Biomass burning emissions estimated with a global fire assimilation system based on observed fire radiative power. *Biogeosciences*, 9(1), 527–554.

Lamarque, J.-F., Bond, T. C., Eyring, V., Granier, C., Heil, A., Klimont, Z., ... others (2010). Historical (1850–2000) gridded anthropogenic and biomass burning emissions of reactive gases and aerosols: methodology and application. *Atmospheric Chemistry and Physics*, 10(15), 7017–7039.

Morcrette, J.-J., Boucher, O., Jones, L., Salmond, D., Bechtold, P., Beljaars, A., ... others (2009). Aerosol analysis and forecast in the european centre for medium-range weather forecasts integrated forecast system: Forward modeling. *Journal of Geophysical Research: Atmospheres*, 114(D6).

Rémy, S., Kipling, Z., Flemming, J., Boucher, O., Nabat, P., Michou, M., ... others (2019). Description and evaluation of the tropospheric aerosol scheme in the european centre for medium-range weather forecasts (ecmwf) integrated forecasting system (ifs-aer, cycle 45r1). *Geoscientific Model Development*, 12(11), 4627–4659.

Rodríguez-Fernández, N. J., Mialon, A., Mermoz, S., Bouvet, A., Richaume, P., Al Bitar, A., ... others (2018). An evaluation of smos l-band vegetation optical depth (l-vod) data sets: high sensitivity of l-vod to above-ground biomass in africa. *Biogeosciences*, 15(14), 4627–4645.
Saatchi, S. S., Harris, N. L., Brown, S., Lefsky, M., Mitchard, E. T., Salas, W., ... others (2011). Benchmark map of forest carbon stocks in tropical regions across three continents. *Proceedings of the national academy of sciences, 108*(24), 9899–9904.

van der Werf, G. R., Randerson, J. T., Giglio, L., Collatz, G. J., Kasibhatla, P. S., & Arellano Jr, A. F. (2006). Interannual variability in global biomass burning emissions from 1997 to 2004. *Atmospheric Chemistry and Physics, 6*(11), 3423–3441.
Figure S1. Biome classification used in this study following van der Werf et al. (2006) with EFOS "extratropical forest with organic soil", EF "extra tropical forest", PEAT "peat", TF "tropical forest", AGOS "agriculture with organic soil", AG "agriculture", SAOS "savanna with organic soil", Sa "savanna"
Figure S2. Statistics of fire occurrence (FO) per biome type as defined in figure S1. Data statistics are derived from 2016 using GFASv1.2 fire radiative power dataset which includes MODIS observations from both TERRA and AQUA platforms. The histogram width is proportional to the biome total land coverage.
Figure S3. Modified normalized mean bias (MNMB) for all AERONET stations using FRP prediction with and without inflation factor and experiments using model 1 and 3. MNMB measures the distance between observation and forecast and is normalized to make it non-dimensionless. It varies between $-2$ and $+2$ and has an ideal value of zero for a perfect model (and perfect observations). Values near the two extremes values of $-2$ and $+2$ signal extreme under and over predictions. Differences are concentrated in Central and South Africa and the Amazon where most of the fire activity took place in September 2016.
Figure S4. *L-VOD vs AGB conversion relationships* as derived from the work of Rodríguez-Fernández et al. (2018) using the datasets from Saatchi et al. (2011); Baccini et al. (2012); Avitabile et al. (2016) to define a benchmark AGB. The red circles represent the logistic regression fit on the median of the AGB data and the shaded intervals the regressions between the 5th and 95th percentiles.
| Id (DM database) | Fire emissions exp ID | IFS-COMPO exp ID |
|------------------|----------------------|------------------|
| 1                | hl6q                 | hl9m             |
| 2                | hl6w                 | hl9o             |
| 3                | hl6x                 | hl9p             |
| 4                | hl6y                 | hl9q             |
| 5                | hl6z                 | hl9u             |
| 6                | hl70                 | hl9v             |
| FRP              | hks3                 | hkuj             |
| FRP + fact       | hks3                 | hkvs             |

Table S1. Fire emission and IFS-COMPO experiment Ids