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The 2018 fire season in North America as seen by TROPOMI: aerosol layer height intercomparisons and evaluation of model-derived plume heights

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GEM-MACH: operational versus experimental version

In this study, an experimental version of the GEM-MACH model was used for simulations (Makar et al., 2018; 2017; 2015a; 2015b; Akingunola et al., 2018), designed for better process representation where processing time is not as crucial a consideration as for the operational code, and where more detailed science representations are desired. Some of the main differences between the experimental and operational versions of GEM-MACH are given in Table S1, below.

Table S1: Process Description / Features for the Operational versus Experimental GEM-MACH

Feature	**Operational**	**Experimental**
Particle size distribution	2-bin sectional approach, with rebinning to 12 bins in key particle microphysical processes	12-bin sectional approach applied throughout.
Cloud microphysics package	Kain-Fritsch (convective), Sundqvist (all other cloud)	P3 cloud microphysics package
Treatment of ammonia	One-way emissions and deposition	Bidirectional NH_3 fluxes (Whaley et al., 2018)
Anthropogenic plume rise formula	Briggs top-of-stack stability function formulation.	Residual buoyancy calculation between individual model layers (Akingunola et al., 2018)
Leaf Area Index information	BELD3 database	Monthly satellite-derived LAI values (Makar et al., 2017)
Methane treatment	Constant background values	Emitted, transported, reacted species.
Gas-phase chemistry solver	Young and Boris	KPP / RODAS3
Meteorological modulation of fugitive dust	Applied to all particulate species emitted as fugitive dust	Applied only to the “crustal material” fraction of fugitive dust emissions.
Particle Deposition	As per Gong et al. (2003): calculation of mass flux leaving layer and transfer to destination layer or surface.	1D semi-Lagrangian advection in the vertical, to prevent discontinuities in the resulting vertical profile of particle mass.
Forest Canopy Shading and	None	As per Makar et al. (2017): three

Turbulence Treatment		additional layers are added to the model to explicitly simulate the attenuation of light and the profile of vertical diffusion within plant canopies.
Coupling with meteorology	One-way: meteorological fields modify the chemical fields.	Two-way (fully coupled): as per Makar et al. (2015); particle direct and indirect effects are incorporated into the modelling framework, allowing meteorology to perturb the chemistry.
Forest Fire Emissions Module	CFFEPSv2.03 (Chen et al., 2019): Off-line calculations using near-real-time satellite hotspot data, a priori meteorological forecast temperature profiles at 5 levels, and 3 coupled models (a fire growth model, a fire emissions model, and a column radiative transfer model; (Anderson et al., 2011).)) to determine the mass of emissions and vertical height reached by smoke plumes. The resulting emissions data into the column are input into GEM-MACH along with other emissions fields. Near-real time fire hotspot information is obtained from three satellite sensors: MODIS, the Advanced Very High Resolution Radiometer (AVHRR), and Visible Infrared Imaging Radiometer Suite (VIIRS)	CFFEPSv4.0. Key differences from v2.03 include: (a) The original C algorithms of v2.03 were converted to Fortran90 (CFFEPSv3.0) and then incorporated into GEM-MACH as an on-line subroutine package; (b) plume rise is calculated internally using GEM's full vertical resolution for temperature profiles (greater resolution in plume rise calculations); (c) particulate emissions are subdivided into all 12 particle bins; (d) due to the use of the on-line paradigm, forest fire emissions may influence the weather, in turn modifying the predicted plume height on subsequent calculations.

	processed through the Canadian Wildland Fire Information System operated by the Canadian Forest Service, Natural Resources Canada. Further details describing the implementation of the GEM-MACH wildfire component within the model can be found in e.g. Munoz-Alpizar et al. (2017); Pavlovic et al. (2016); Chen et al. (2019).	

MISR OSSE with different refractive indices

The black carbon (BC) reflective index (1.68+0.36i, RH: 99%) has an extremely large imaginary component, in contrast to the refractive index of organic carbon (OC) where the refractive index is 1.36 + 0.001i (at RH=99%).

Looking at these two extreme cases of refractive indices, little difference was found for the MISR OSSE plume heights, most plume heights were very similar, see Fig.S1. Only for profiles with a small plume above a larger one were differences found: the estimates assuming BC returned the plume height of the upper plume whereas the estimates assuming OC picked up the lower plume (see Fig. S2).

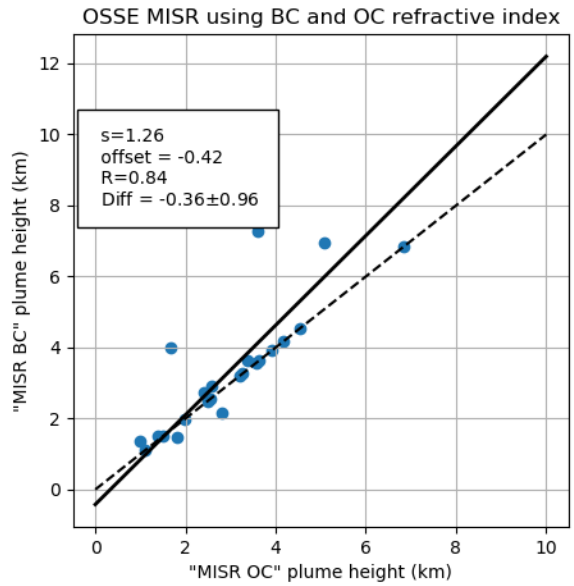

Fig. S1: Scatterplot of MISR OSSE plume height estimates assuming a refractive index appropriate for BC and OC. The plume heights are very similar except for three cases (shown in Fig. S2) where the plume height assuming BC is higher than the plume height assuming OC.

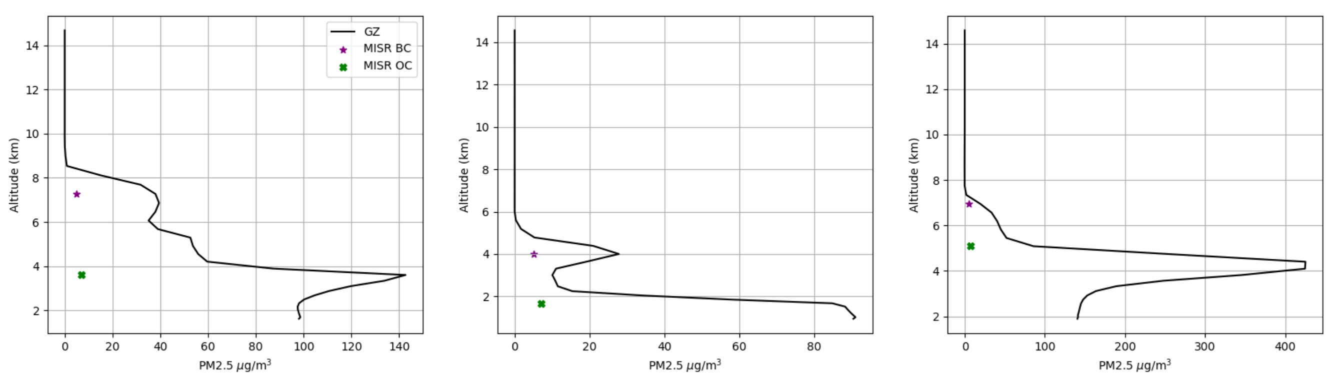

Fig. S2: The three profiles that lead to different plume heights when assuming a refractive index for OC versus BC. This occurs when there is a secondary, smaller plume above the main plume as a result of increased backscattering for BC aerosols.

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