Review2#:

In this document, reviewers' comments have been addressed point by point. Referee comments are shown in black italics and author responses are shown in blue regular text. A manuscript with tracking changes is submitted separately.

Review of Development and evaluation of the interactive Model for Air Pollution and Land Ecosystems (iMaple) version 1.0 by Xu Yue et al.
The paper describes a substantial upgrade to the YIBs model, the paper is well laid out and generally has an appropriate amount of detail on the model description and evaluation. I agree with the final conclusion that the new model is well suited for studying climate-chemistry-ecosystem interactions, either driven by atmospheric data or coupled to an atmospheric model. There are several places where the text could be clearer or a little more detail could be added, I list these below.

➡Thanks for your positive comments, and we added more details as suggested in the revised paper.

General: Please can you add a table that lists all parameters, their values and units?

➡In our revised paper, we listed all parameters into Tabel S1 as suggested.

Line 143: In section 2.1, please can you state if each gridbox has a single PFT, or a mixture of PFTs? If it is a mixture of PFTs, do all PFTs share a single soil column (all draw from the same soil moisture store)?

➡In the revised paper, we added more explanations on PFTs in the model as follows: "At each grid, a mixture of PFTs with each PFT fraction is used as model input, sharing the temperature or moisture information from the same soil column." (Lines 155-157)

Line 184: How are ECAN and EGRO calculated? TWS doesn't include a canopy storage term, so what storage term is the ECAN flux taken from?

➡In our revised paper, we added the equations on calculations of ECAN and EGRO, and explained that ECAN fluxes are from canopy interception of precipitation as follows:

"Meanwhile, $ECAN$ is calculated as follows:

$$ECAN = \frac{\rho_{air} \cdot CP_{air} \cdot C_{canopy,evap} \cdot (e_{sat} - e_{ca})}{PC} \tag{4}$$

$$C_{canopy,evap} = \frac{f_{wet} \cdot E_{VAI}}{R_{leaf,bdy}} \tag{5}$$

Here, $C_{canopy,evap}$ is the latent heat conductance from the wet leaf surface to canopy air. f_{wet} is the wetted fraction of canopy, which is a fraction of the maximum canopy precipitation interception capacity. E_{VAI} is the effective vegetation area index and $R_{leaf,bdy}$ is bulk leaf boundary resistance. $EGRO$ is calculated as follows:

$$EGRO = C_{ground,evap}(e_{sat,ground}RH - e_{ca}) \tag{6}$$

Here, $C_{ground,evap}$ is the coefficient for latent heat, $e_{sat,ground}$ is the saturated vapor pressure at the ground and RH is the surface relative humidity." (Lines 202-211)

Line 200: "Here, we assume independent and exponential distributions of infiltration capacity and precipitation in each grid cell when considering soil infiltration processes and Qsoil,in is the infiltration into the soil, following the approach by Schaake et al. (1996)." I don't understand this sentence, please can you expand on what you mean. Do you mean each grid cell is independent of all other grid cells? Or that infiltration capacity is independent of precipitation? Do you mean that there is an exponential relationship between infiltration capacity and precipitation?

➔In our revised paper, we expanded original descriptions and further added equations on calculations of infiltration capacity in each grid cell as follows:
"$Q_{soil,in}$ is the infiltration into the soil, which is derived from approximate solutions of Richards equations with considerations of the spatial variations in precipitation and infiltration capacity. Here, we assume exponential distributions of infiltration capacity in each grid cell following the approach by Schaake et al. (1996):

$$Q_{soil,in} = Q_{soil,srf} \frac{I_c}{Q_{soil,srf}\Delta t + I_c} \tag{9}$$

$$I_c = W_d[1 - \exp(-K_{\Delta t}\Delta t)] \tag{10}$$

Here, I_c and W_d are the soil infiltration capacity of the model grid cell and the water deficit of the soil column, respectively. $K_{\Delta t}$ and Δt are the calibratable parameters and model time step." (Lines 218-227)

Line 206: Does K4 vary spatially? If it does vary spatially, what dataset is used to calculate K4?

➔In our revised paper, we added more explanations on calculating K_4 as follows:

"K_4 is the hydraulic conductivity in the bottom soil layer parameterized following the scheme in Clapp and Hornberger (1978) and is calculated using spatial soil profiles from Hengl et al. (2017)." (Lines 230-232)

Line 215: The model's soil column is only 2m deep, was that depth inherited from Noah-MP, or chosen by the authors? I think a deeper soil column would improve the ecosystem representation and interactions with climate, particularly during drier conditions. Perhaps, you could comment on the choice of soil of total soil depth in the discussion.

➜Thanks for your questions. The soil column in iMAPLE model is inherited from original Noah-MP model, and we added more discussion in the last section as follows: "Meanwhile, iMAPLE model considers only dynamic soil water and temperature at 2-m level, which may influence the deeper soil interactions between climate and land terrestrial ecosystem especially for the drier conditions." (Lines 709-711)

Line 240: In section 2.2.2, please state that simulated burnt area has not impact on vegetation, or feedback onto fuel load. I appreciate this is mentioned in the discussion, but I think it should be mentioned here too.

➜In our revised paper, we added more descriptions on fire modules of iMAPLE model as follows:
"It is important to note that the feedbacks of fire activities on terrestrial ecosystems have not been considered in the current version of iMAPLE model due to the high complexity." (Lines 313-315)

Line 254: What are the units of PD?

➜The unit of PD is Number km^{-2}, and units of all parameters used in this study are shown in Table S1.

Line 261: This function is complicated, it is difficult to know how the burnt area is related to the atmospheric drivers. Please can you plot BA as a function of U for a fixed RH, and plot BA as a function of RH for a fixed U? If plots of these relationships exist in Pechony and Shindell (2009) or Li et al. (2012), you could refer to their figures, but it would still be good to add some description of the relationships, e.g. does BA depend strongly on U, is RH more important, what happens if U is zero?

➜In our revised paper, we plotted relationships between burned area (BA) and U, RH as Figure R1, and added more explanations on relationships between burned area and atmospheric drivers (e.g., wind speed and relative humidity) as follows:
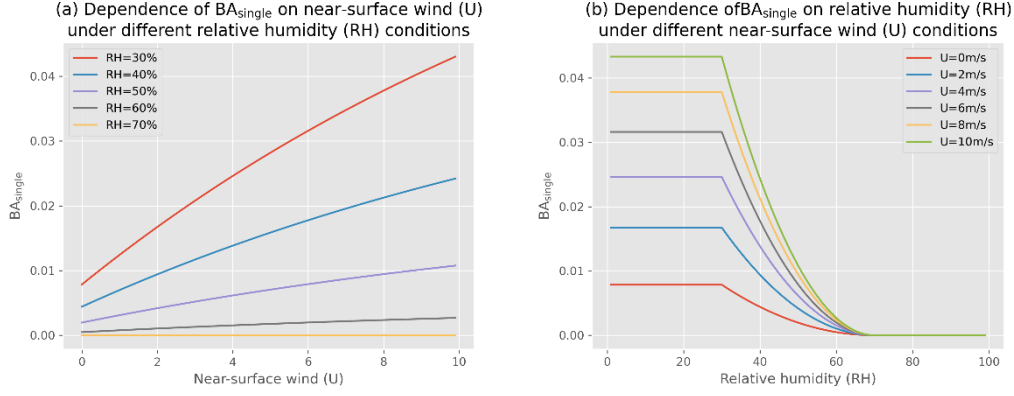
Figure R1. The dependences of BA_{single} on (a) near-surface wind speed (U) and (b) relative humidity (RH), respectively.

"In general, the eccentricity of burned area is primarily influenced by near-surface wind speed, while the rate of fire spread is jointly regulated by near-surface wind speed and relative humidity. The shape of the fire is converted to a circular form when the near-surface wind speed reaches zero, and burning ceases to propagate once the relative humidity is above a specific threshold." (Lines 302-306)

Line 270: Why were these values of RHlow and RHup chosen?

➔In our revised paper, we explained reasons for choosing RH_{low} and RH_{up} as follows: "In this study, we set RH_{low} =30 % and RH_{up} =70 % as the lower and upper thresholds of RH following the methods used in Li et al. (2012). If RH is higher than 70%, natural fires will not occur or spread, and RH will no longer be a constraint factor for fire occurrence and spread if RH ≤ 30%." (Lines 297-300)

Line 298: Should the left hand side of equation 30 be "fTS" and not "Q10"?

➔Thanks for your questions, and we added formula on calculating F_{TS} to avoid misunderstanding as follows:
"The impact factor of soil temperature f_{ST} can be calculated as follows (Zhang et al., 2002; Zhu et al., 2014):

$$f_{ST} = \begin{cases} 0, & T_s < T_{min} \\ vt^{xt} \exp(xt(1 - vt)), & T_{min} \leq T_s \leq T_{max} \\ 0, & T_s > T_{max} \end{cases} \qquad (35)$$

$$vt = (T_{max} - T_s)/(T_{max} - T_{opt}) \qquad (36)$$

$$xt = \left[\log(Q_{10})\left(T_{max} - T_{opt}\right)\right]^2 (1.0 + at^{0.5})^2/400.0 \qquad (37)$$

$$at = 1.0 + 40.0/[\log(Q_{10})(T_{max} - T_{opt})] \qquad (38)$$

T_{min}, T_{max}, and T_{opt} represents the lowest, highest and optimum temperature for the process of methane production and oxidation, respectively. In this study, the $T_{min} = 0°C$, $T_{max} = 45°C$ and $T_{opt} = 25°C$ (Zhu et al., 2014)." (Lines 336-345)

Line 363: How do you solve equations 36 and 38? Do you use an iterative process?

➔Thanks for your questions. The original equations 36 and 38 are now 45 and 47 in the revised paper, respectively. We clarified as follows:
"The f_{O3} in Equation (45) is fed into Equation (47) so as to build a quadratic equation for F. We solve the quadratic equation and select the *F* value within the range of [0, 1]." (Lines 420-422)

Line 385: How is the spin-up run? What driving data is used?

➔In our revised paper, we clarified the spin-up processes as follows:
"We run the model for the period of 1980-2021 using the initial conditions of the equilibrium soil carbon pool, tree height, and water fluxes from a spin-up run of 200 years driven with cycled forcing at the year 1980." (Lines 444-447)

Line 399: Is LMA PFT-specific? Are you using a different map of LMA for each PFT?

➔In our model, the LMA map has no PFT information but shows specific values for each individual grid. We clarified as follows:
"For the LMA-based O_3 damage scheme, we use gridded LMA from the trait-level dataset of TRY (Kattge et al., 2011) developed by extending field measurements with the random forest model (Moreno-Martínez et al., 2018)." (Lines 461-464)

Line 418: Please state that CMIP6 anthropogenic CH4 emissions are used for context and not for validation purposes.

➔In our revised paper, we moved this part into the Section 2.2.3 as follows:
"We implement the process-based wetland CH_4 emissions into the iMAPLE model. The anthropogenic sources of CH_4 from Coupled Model Intercomparison Project phase 6 (CMIP6, https://esgf-node.llnl.gov/projects/input4mips/) are also used as input for iMAPLE." (Lines 318-321)

Line 440: In addition to biases in meteorological input, it would be good to acknowledge that 1x1 degree gridded simulations would not be expected to match site-level observations, because of differences in vegetation cover and soil properties.

➔In our revised paper, we added further discussion on biases of simulations as follows: "The biases in the meteorological input may cause uncertainties in the simulation of GPP fluxes (Ma et al., 2021). In addition, the mismatch of vegetation cover and soil properties between the site location and 1°×1° grid in the simulation may further contribute to the modeling biases." (Lines 500-503)

Line 442: Why would the increase in site number and record length decrease R?

➔Considering these inappropriate descriptions, we deleted this sentence in our revised paper.

Line 482: In this paragraph, it would be good to include the global total GPP in Pg/yr. This would allow easy comparison to other estimates.

➔We added global total GPP using the units of Pg yr^{-1} in our revised paper as follows: "On the global scale, our simulations yield a total GPP of 129.8 Pg C yr^{-1}, similar to the observed amount of 125.4 Pg C yr^{-1}." (Lines 549-550)

Line 512: This paragraph and figure 9 would be better if fire emissions were evaluated. The paper and the model have a focus on climate-chemistry-ecosystem interactions, and fire has been included in order to simulate emissions, not particularly to predict burnt area.

➔ Thank you for your suggestions. In the revised paper, we added evaluations of simulated fire-emitted OC emissions using GFED products in Figure 9 and more descriptions as follows:
"Furthermore, we compare fire-emitted OC from the model with GFED4.1s. The spatial pattern of OC emissions is similar to that of burned area. The simulations yield a total of 16.8 Tg yr^{-1} for the global fire-emitted OC, slightly higher than the amount of 16.4 Tg yr^{-1} from GFED4.1s with some overestimations in tropical Africa (Figure 9f)." (Lines 591-595)
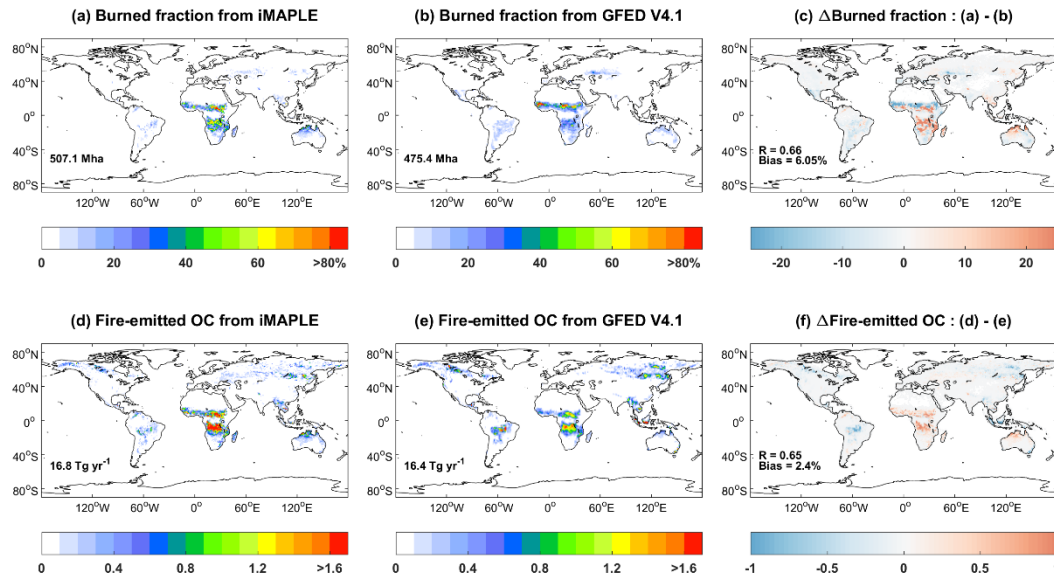
Figure 9 Comparisons of global burned fraction (%) and fire-emitted OC emissions (10^{-3} kg km^{-1} yr^{-1}) between (a, d) simulations and (b, e) observations. Simulations are performed using iMAPLE and observations are from GFED V4.1 fire emissions products. Both simulations from BASE experiment and observations are averaged for the 1997-2016 period. The global total area burned are shown on (a) and (b), and total OC emissions are shown on (d) and (e). The spatial difference, correlation coefficient (R), and normalized mean biases between simulations and observations are shown on (c) and (f).

Line 624: "As a result, the interactions between fire and ecosystems are underestimated in the current model framework." Can you speculate on how these interactions would affect your results? My guess is that the lack of feedback from burnt area to fuel load, means that the model will overestimate burnt area and fire emissions.

➜In our revised paper, we added discussions on fire feedbacks as follows:
"As a result, the interactions between fire and ecosystems are underestimated in the current model framework, potentially leading to overestimations of wildfire activity due to remaining fuel loads." (Lines 701-704)

Line 629: Instead of "refrain", perhaps "limits" or "prevents" would be better words to use.

➜Corrected as suggested.

Figure 6: Could consider using a colourblind friendly colour scale. I don't know if the journal has a policy on this.

➜Corrected as suggested.

Figure 9: Would be improved by including a maps of fire emissions from iMAPLE and GFED. I'm not sure what emissions data GFED provides, but emissions of a single species would be sufficient.

➔Thanks for your suggestions. We added validations of simulated fire-emitted OC with GFED products into Figure 9 and more descriptions as follows:
"Furthermore, we compare fire-emitted OC from the model with GFED4.1s. The spatial pattern of OC emissions is similar to that of burned area. The simulations yield a total of 16.8 Tg yr^{-1} for the global fire-emitted OC, slightly higher than the amount of 16.4 Tg yr^{-1} from GFED4.1s with some overestimations in tropical Africa (Figure 9f)." (Lines 591-595)
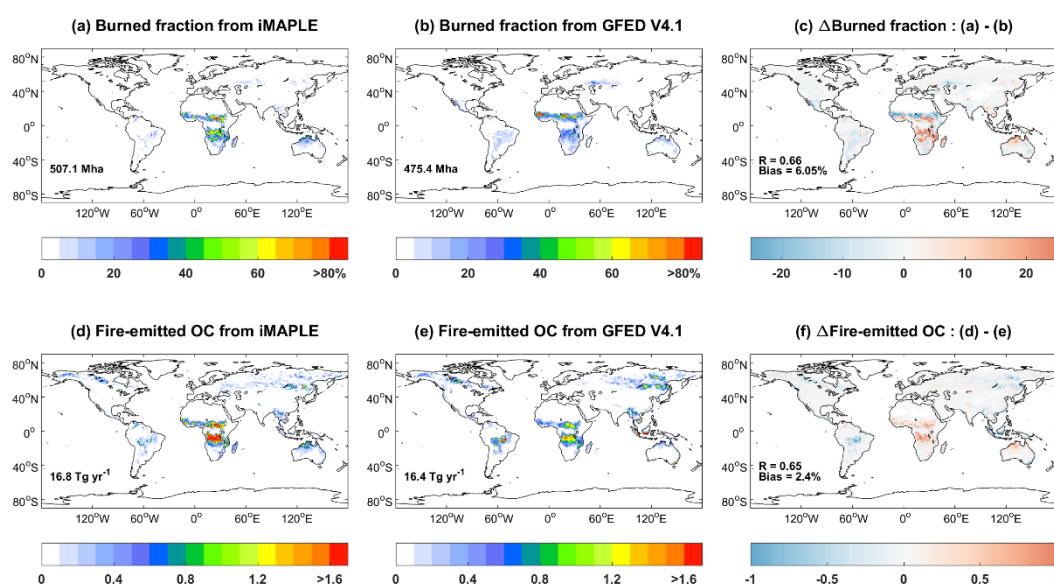

Figure 9 Comparisons of global burned fraction (%) and fire-emitted OC emissions (10^{-3} kg km^{-1} yr^{-1}) between (a, d) simulations and (b, e) observations. Simulations are performed using iMAPLE and observations are from GFED V4.1 fire emissions products. Both simulations from BASE experiment and observations are averaged for the 1997-2016 period. The global total area burned are shown on (a) and (b), and total OC emissions are shown on (d) and (e). The spatial difference, correlation coefficient (R), and normalized mean biases between simulations and observations are shown on (c) and (f).

Figure 10: Would be improved by adding maps of soil carbon and wetland area.

➔We understood these concerns on sources of CH$_4$ emissions. In the global natural wetlands, CH$_4$ productions are commonly associated with anaerobic conditions. Heterotrophic respiration can regulate the ratio of carbon dioxide to methane by influencing the accumulation of soil organic matter which can provide available substrate for CH$_4$ production. As a result, we added maps of wetland area and

heterotrophic respiration instead of soil carbon into Figure 10 with more descriptions as follows:

"As important factors driving CH$_4$ emissions, heterotrophic respiration shows higher values over tropical regions and eastern China with a total amount of 73.2 Pg C yr^{-1} (Figure 10c), and relative high wetland coverages are found in boreal Asia and Amazon (Figure 10d)." (Lines 607-610)
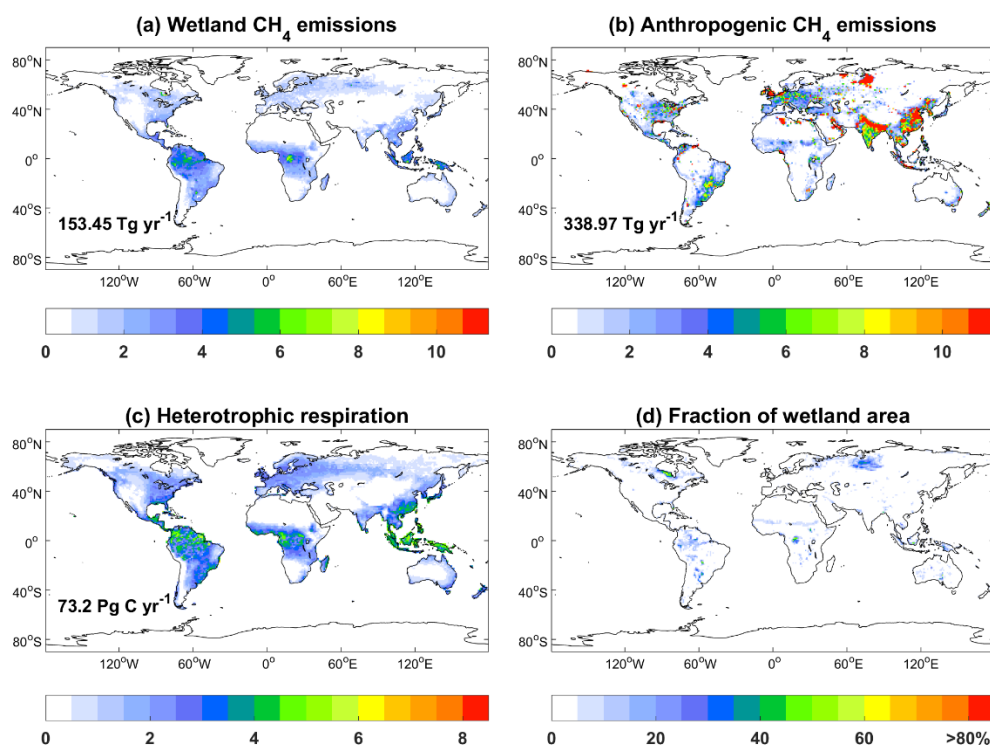

Figure 10 Global simulated CH$_4$ emissions (g [CH4] m^{-2} yr^{-1}) from (a) wetland and (b) anthropogenic sources, (c) heterotrophic respiration (gC m^{-2} day^{-1}) and (d) fraction of wetland area. Anthropogenic sources include energy, agriculture, industrial, residential, shipping, solvent and transportation from CMIP6 input. The simulations are from BASE experiment. The global total emissions and heterotrophic respirations are shown on each panel. All variables are averaged for 2000-2014.

Figure 10: In the caption, please could you be clear that wetland emissions are simulated by iMAPLE and anthropogenic sources are taken from input4mips.

➔In our revised paper, we added more explanations on caption in Figure 10 as suggested.