Response to Reviewers' Comments on "Influence of plant ecophysiology on ozone dry deposition: Comparing between multiplicative and photosynthesis-based dry deposition schemes and their responses to rising CO_2 level" by Sun et al.

The comments of the referee are given as plain text, while the authors' response is given in *italic.* We have revised the paper based on the reviewers' comments.

Response to Referee #1

In this paper, the authors use a standalone terrestrial biosphere model to evaluate both multiplicative and photosynthesis-based schemes of stomatal conductance of ozone. Observational datasets of the dry deposition velocity and the stomatal conductance of ozone are used to do the model evaluation. The authors suggested that the photosynthesis-based stomatal algorithms that captured the responses to water stress had a better agreement with the observations. The manuscript describes a straightforward modeling study exploring basic parameterizations and comparisons to observations, and fits into the scope of Biogeosciences. I have a few minor comments as listed below.

- *We thank the referee for the very helpful comments and suggestions. The paper has been revised accordingly. Our point-by-point responses are provided below.*

My major concern is that based on the model-observation comparison in this paper, I do not see a significant improvement by using photosynthesis-based stomatal conductance methods, compared to the traditional multiplicative methods. The default multiplicative W89 scheme without stomatal response to water stress fails to reproduce the diurnal variations in Gs, but the multiplicative Z03 method seems to agree well with the other photosynthesis-based methods and the observations. Furthermore, all schemes compare poorly with observations in rainforests and in the Blodgett forest site (which is often associated with higher temperatures and water stress). Can the authors comment a bit more on the advantages of using photosynthesis-based methods?

- *We very much agree that using photosynthesis-based stomatal conductance models do not significantly improve model performance over Z03, and that Z03 agrees well with photosynthesis-based methods. In the paper, we have therefore mentioned this at various places, highlighting that both photosynthesis-based schemes and Z03 multiplicative schemes are better than W89, mostly likely due to their ability to capture plant responses to water stress and VPD, e.g., P15 L442: "… In general, accounting for stomatal response to VPD and/or water* *stress using multiplicative or photosynthesis-based stomatal algorithms can improve model performance in capturing diurnal variations of G_s and v_d."*

- *The merits of multiplicative methods such as lower computational costs and higher compatibility are undeniable for Earth system modeling. Multiplicative methods parameterized with observations can also be improved whenever more field measurements are available. Yet, with more biophysically meaningful and measurable properties, photosynthesis-based methods are principally more mechanistic than multiplicative stomatal methods, and can better address plant responses to a changing environment (e.g., rising CO_2 and temperature) with rapidly expanding knowledge from biologists. Furthermore, parameters for photosynthesis-based methods can be obtained from leaf-scale measurements, which overall cost less than dry deposition flux measurements that are used for parameterizing multiplicative model. We have now emphasized these points more in the Conclusions and Discussion, e.g., P26 L681: "Our attempt to include the empirical CO_2 response function of Franks et al. (2013) in multiplicative stomatal schemes result in a much larger reduction in global G_s that doubled the average relative change computed with photosynthesis-based stomatal schemes, and potentially overstates stomatal responses to elevated CO_2 under future scenarios."*

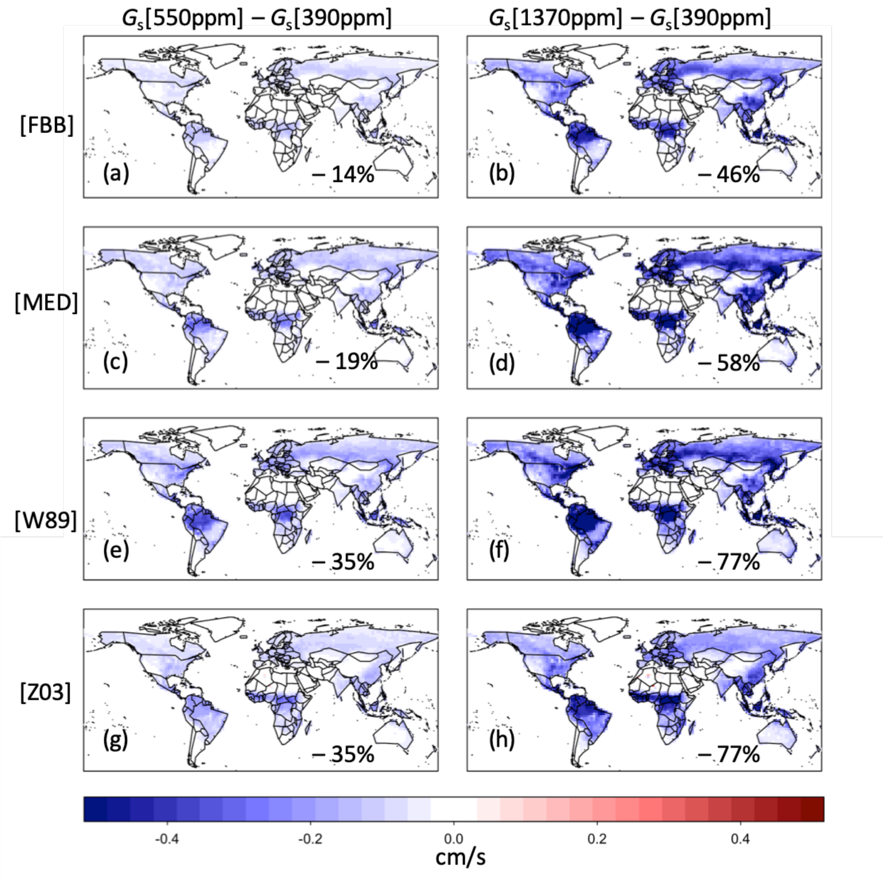
The numbers and names of the modeling schemes are sometimes confusing. For example, the words "multiplicative" and "photosynthesis-based" in the title refer to stomatal conductance schemes, not dry deposition schemes, right? In the abstract, the Medlyn scheme is also a photosynthesis-based method, so there are actually two multiplicative (W89, Z03), two photosynthesis-based (FBB, MED) stomatal conductance schemes. I think it should be stated clearly in the abstract and introduction, or it will confuse the readers.

- *Thanks for your suggestions. Yes, "multiplicative" and "photosynthesis-based" refer to stomatal conductance schemes. The relevant parts are revised accordingly.*

"We developed and used a standalone terrestrial biosphere model, driven by a unified set of prescribed meteorology, to evaluate two widely used dry deposition modeling frameworks, Wesely (1989) and Zhang et al. (2003), with different configurations of stomatal resistance: 1) the default multiplicative method in the Wesely scheme (W89) and Zhang et al. (2003) scheme (Z03); 2) the traditional photosynthesis-based Farquhar-Ball-Berry (FBB) stomatal algorithm; 3) the Medlyn stomatal algorithm (MED) based on optimization theory."

Also, the figures should be consistent to show all 6 schemes when comparing to observed dry deposition velocity Vd, and show all 4 schemes when comparing to observed stomatal conductance Gs. For example, why not compare the Z03 scheme in Figure 11?

- *Thank you for your suggestion. We updated the Figure 11 to make it consistent.*



L42: Does this "45%" refer to an annually averaged percentage? How does this compare to your results? As the stomatal conductance is the main focus of this paper, I would suggest moving Figure S3 (showing the fraction of stomatal conductance to total deposition) to the main text.

- *Thanks for the suggestion. Yes "45%" refers to annual daytime average (Clifton et al., 2020), which is stomatal fraction of ozone dry deposition aggregated from previous literature. We aggregate annual daytime stomatal fraction here using SynFlux: W89 (87%), Z03 (62%), FBB (65%), MED (68%). Stomatal fractions in Clifton et al. (2020) are calculated with P-M method. Our results show that Z03 and FBB agree with P-M derived stomatal conductance. Simulated higher stomatal fractions can be related with underestimation of non-stomatal conductance. Not all datasets in Clifton et al. include data from all seasons. The* *magnitude of stomatal fraction is also affected by vegetation types: deciduous forest has higher stomatal fraction than other vegetation types. We have now revised the relevant parts and moved Figure S3 to main text as suggested.*

L257: Please briefly explain the P-M method here.

- *We have now explained the P-M method in the Supplementary.*

  "We use evaporative-resistance form of Penman-Monteith method to keep consistent with SynFlux stomatal conductance. The leaf stomatal conductance is:

  $$g_w^{-1} = \frac{\varepsilon\rho(e_s(T_f)-e)}{pE} - (r_a + r_{b,w}),$$

  where ε is mass ratio between water and dry air, p is air pressure, E is surface moisture flux, T_f is leaf temperature, $e_s(T_f)$ is the saturation vapor pressure at leaf surface. r_a is aerodynamic resistance, $r_{b,w}$ is quasi-laminar layer resistance to water vapor. T_f is estimated as follows:

  $$T_f = T + \frac{H(r_a+r_{b,H})}{c_p\rho},$$

  where T is air temperature, H is sensitive heat, c_p is specific heat of air, ρ is the mass density of air, $r_{b,H}$ is quasi-laminar layer resistance to heat.

  Stomatal conductance of O_3 is calculated with molecular diffusion coefficient ratio 0.6 between O_3 and water vapor:

  $$g_s = 0.6 g_w$$ "

Table 3: This table contains a lot information and is not easy to read. How about using some background colors, e.g., red/blue to show overestimation/underestimation and dark/light colors to indicate large/small bias?

- *Thank you for the suggestion. Updated Table 3 with background colors.*

PFT	Season	Observation	W89			W89FBB			W89MED			Z03			Z03FBB			Z03MED		
		mean±sd	mean±sd	NMBF	NMAEF	mean±sd	NMBF	NMAEF	mean±sd	NMBF	NMAEF	mean±sd	NMBF	NMAEF	mean±sd	NMBF	NMAEF	mean±sd	NMBF	NMAEF
DBF	JJA	0.69±0.10	0.90±0.17	0.32	0.32	0.59±0.10	− 0.16	0.26	0.81±0.24	0.18	0.41	0.55±0.09	− 0.25	0.30	0.58±0.11	− 0.18	0.26	0.78±0.25	0.14	0.41
	MAM	0.33±0.02	0.42±0.13	0.27	0.43	0.28±0.08	− 0.21	0.23	0.35±0.10	0.05	0.26	0.29±0.08	− 0.13	0.27	0.31±0.05	− 0.09	0.18	0.37±0.08	0.10	0.21
	SON	0.52±0.20	0.49±0.12	− 0.05	0.18	0.29±0.07	− 0.78	0.78	0.39±0.13	− 0.34	0.34	0.41±0.06	− 0.26	0.26	0.37±0.05	− 0.39	0.39	0.46±0.11	− 0.11	0.13
	DJF	0.25±0.08	0.14±0.05	− 0.86	0.97	0.14±0.05	− 0.86	0.86	0.15±0.06	− 0.72	0.87	0.24±0.04	− 0.04	0.21	0.26±0.03	0.02	0.23	0.26±0.04	0.05	0.27
ENF	JJA	0.58±0.23	0.46±0.12	− 0.29	0.35	0.46±0.11	− 0.30	0.42	0.47±0.10	− 0.27	0.40	0.42±0.14	− 0.39	0.68	0.52±0.14	− 0.14	0.44	0.53±0.13	− 0.12	0.42
	MAM	0.46±0.15	0.35±0.11	− 0.31	0.43	0.34±0.10	− 0.34	0.40	0.37±0.12	− 0.24	0.37	0.42±0.06	− 0.10	0.31	0.43±0.09	− 0.07	0.26	0.46±0.11	− 0.01	0.26
	SON	0.47±0.22	0.35±0.12	− 0.35	0.43	0.28±0.07	− 0.64	0.68	0.26±0.04	− 0.83	0.85	0.39±0.13	− 0.21	0.46	0.41±0.15	− 0.13	0.37	0.40±0.12	− 0.18	0.43
	DJF	0.32±0.21	0.17±0.07	− 0.87	0.89	0.19±0.08	− 0.66	0.73	0.16±0.06	− 0.98	1.01	0.30±0.11	− 0.08	0.29	0.30±0.15	− 0.05	0.28	0.28±0.12	− 0.14	0.36
CRO	/	0.53±0.16	0.50±0.26	− 0.05	0.29	0.72±0.15	0.37	0.43	0.81±0.13	0.54	0.54	0.54±0.11	0.03	0.18	0.61±0.15	0.16	0.32	0.67±0.14	0.27	0.32
TRF	/	0.76±0.48	1.11±0.07	0.46	0.56	0.98±0.06	0.29	0.52	1.10±0.10	0.44	0.53	0.47±0.05	− 0.60	0.85	0.57±0.04	− 0.33	0.61	0.66±0.07	− 0.14	0.48
GRA	JJA	0.33±0.17	0.72±010	1.21	1.21	0.59±0.21	0.82	0.82	0.84±0.28	1.56	1.56	0.50±0.12	0.53	0.79	0.50±0.16	0.51	0.51	0.68±0.21	1.08	1.08
	MAM	0.39±0.13	0.58±0.13	0.48	0.48	0.43±0.00	0.08	0.28	0.62±0.16	0.57	0.74	0.42±0.11	0.06	0.48	0.46±0.03	0.17	0.36	0.62±0.15	0.56	0.72
	SON	0.30±0.06	0.59±0.21	1.00	1.20	0.46±0.22	0.55	0.78	0.55±0.26	0.88	1.03	0.42±0.29	0.43	0.76	0.46±0.20	0.54	0.80	0.54±0.22	0.82	0.95
	DJF	0.33±0.05	0.34±0.26	0.02	0.68	0.24±0.14	− 0.37	0.56	0.34±0.31	0.04	0.77	0.31±0.15	− 0.08	0.46	0.35±0.18	0.06	0.49	0.443±0.32	0.31	0.79

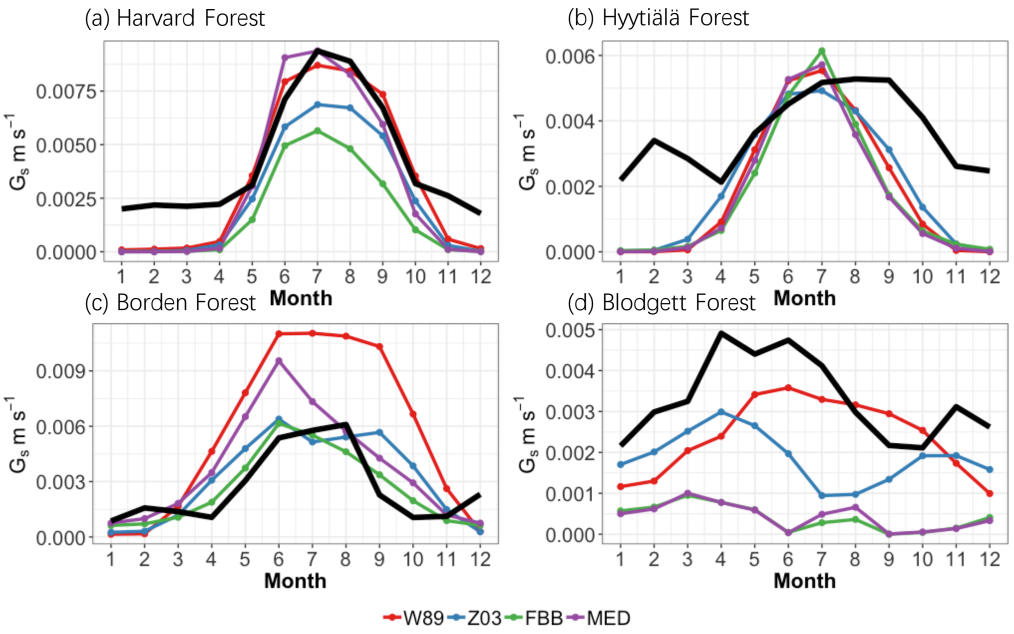
L327 Not sure what this sentence means. Do you mean ozone reacts “with” soil-emitted NO and BVOC here?

- *Yes. Revised as suggested:*

  “Non-stomatal O_3 deposition includes chemical reactions of O_3 with nitric oxide (NO) and biogenic volatile organic compounds (BVOC) from soil emissions (Fares et al., 2012).”

Figure 2 The models seem to predict an overall earlier peak than the observations. Can the authors comment on why it could be?

- *Simulated monthly daytime v_d peaks in around June to July, while observed daytime v_d peaks during July to August. As we used observed LAI in this study, LAI is not the major driver as in previous studies. For long-term sites in Figure 2, overestimation of stomatal conductance and underestimation of non-stomatal conductance cause discrepancies between modelled and observed v_d. Simulated and observed monthly daytime average stomatal conductance variations are shown in the figure below. The peaks in early summer are mainly driven by stomatal conductance, due to favorable conditions such as higher solar radiation and lower VPD.*



L401 which site is "ponderosa pine forest"? Include the site name here.

- *Blodgett Ameriflux site. Revised as suggested:*

  "The major O_3 removal process in the ponderosa pine plantation at the Blodegett Ameriflux site is non-stomatal O_3 sink through in-canopy chemical reactions between O_3 and BVOC (Fares et al., 2010; Kurpius and Goldstein, 2003)."

Finally, this manuscript includes many abbreviations and sometimes is hard to follow. I would suggest including a list of abbreviations and explanations if possible.

- *Thanks for your suggestion. Revised as suggested.*

Table. List of abbreviations used in this paper with descriptions.

Symbol	Description
A_n	leaf net CO_2 assimilation rate
BVOC	biogenic volatile organic compounds
CLM	Community Land Model
CRO	Crop
C_s	CO_2 concentration at the leaf surface
CTMs	chemical transport models
DBF	Deciduous Broadleaf Forest
D_i	molecular diffusivities for water
DO$_3$SE	The Deposition of O_3 for Stomatal Exchange
D_v	molecular diffusivities for pollutant gas
ENF	Evergreen Needleleaf Forest
ESMs	Earth system models

FBB	Farquhar-Ball-Berry stomatal scheme
g_0	PFT-dependent minimum stomatal conductance
g_{1B}	fitted slope parameter for Ball-Berry model
g_{1M}	fitted slope parameter for Medlyn model
GRA	Grass
G_s	Canopy stomatal conductance
h_s	leaf surface relative humidity
L	Obukhov length
LAI	leaf area index
L^{sha}	shaded LAI
LSMs	land surface models
L^{sun}	sunlit LAI
MAP	mean annual precipitation
MED	Medlyn stomatal scheme
MERRA-2	Modern-Era Respective analysis for Research and Applications version 2
MODIS	Moderate Resolution Imaging Spectroradiometer
NMAEF	normalized mean absolute error factor
NMBF	normalized mean bias factor
NO	nitric oxide
O_3	ozone
P-M	Penman-Monteith
PAR	photosynthetically active radiation
PFTs	plant functional types
P_r	the Prandtl number for air
R^2	*R*-squared value
R_a	aerodynamic resistance
R_{ac}	in-canopy aerodynamic resistance
R_{adc}	lower canopy aerodynamic resistance
R_{ag}	ground aerodynamic resistance
R_b	quasi-laminar sublayer resistance
r_b	leaf boundary resistance
R_c	bulk surface resistance
R_c	canopy resistance
R_{clx}	lower canopy resistance
R_{cut}	cuticular resistance
R_{cutd0}	reference cuticular resistance for dry condition
R_{cutw0}	reference cuticular resistance for wet condition
R_g	ground resistance
RH	relative humidity
R_s	stomatal resistance
r_{smin}	minimum stomatal resistance
r_s^{sha}	shaded stomatal resistance

r_s^{sun}	sunlit stomatal resistance
RuBP	ribulose 1,5-bisphosphate
S_r	the Schmidt number
SRAD	incoming shortwave solar radiation
SW	soil wetness
T	surface temperature
TEMIR	Terrestrial Ecosystem Model in R
TRF	Tropical Rainforest
u_*	friction velocity
v_d	dry deposition velocity of O_3
VPD	vapor pressure deficit
W89	Wesely deposition scheme
W89FBB	Wesely deposition scheme replaced with Faquhar-Ball-Berry stomatal scheme
W89MED	Wesely deposition scheme replaced with Medlyn stomatal scheme
W_{st}	stomatal blocking factor
z	reference height
z_0	roughness height
Z03	Zhang et al. (2003) deposition scheme
Z03FBB	Zhang et al. (2003) deposition scheme replaced with Faquhar-Ball-Berry stomatal scheme
Z03MED	Zhang et al. (2003) deposition scheme replaced with Medlyn stomatal scheme
κ	von Kármán constant
ψ	water stress