Response to Referee #2 comment on "A Simplified Chemistry-Dynamical Model" by Hao-Jhe Hong and Thomas Reichler, Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2021-149-RC2, 2021

This paper describes a simplified chemistry-dynamical model (SCDM), which consists of a dry dynamical core, a simple linear ozone scheme, and an ozone shortwave parameterization. In the SCDM, stratospheric chemistry couples with dynamics through ozone shortwave absorption. Ozone concentrations are determined by transport and photochemical tendencies calculated from the linear ozone scheme. Changes in ozone affect temperature and dynamics through shortwave absorption. SCDM climatology is validated against MERRA2 in terms of ozone, shortwave radiation, and dynamical fields. In addition, ozone and dynamical variability associated with the Arctic stratospheric sudden warming (SSW) events in SCDM are compared to that in MERRA2. Overall, the SCDM simulates reasonably well the climatology and variability of stratospheric ozone and dynamics.

Interactive stratospheric ozone chemistry has been shown to play a key role in stratosphere-troposphere coupling. Given its simplicity and computational efficiency in relative to the comprehensive chemistry-climate models, the SCDM provides a potentially useful tool to understand the stratospheric chemical-dynamical coupling. The paper is well written. The description of the model is clear. I recommend publication after my comments are addressed.

Comments:

The SCDM simulates well the Arctic SSWs. Does it also capture the Antarctic temperature and wind variability? I suggest adding a figure like Figure 9 for wind and temperature.

We now add to the paper an analysis for temperature and wind variability over the Arctic and Antarctic. The new Fig. 9 (or Fig. R4 below) reveals that the model also captures reasonably well the circulation and ozone variability over the Antarctic. In the revised manuscript we add a brief discussion of the new figure. Please see line 225 and 229 in the revised manuscript, where we write:

L225: *"…We therefore examine next how this variability affects the circulation and ozone over the two polar caps (Fig. 9)."*

L229: *"In MERRA2 over the Arctic (Fig. 9a, e, i), the variability of lower stratospheric zonal wind, temperature, and ozone (below 10 hPa) strengthens from November and reaches a maximum during February-March. The increased variability is associated with intermittently enhanced planetary wave forcing (Fig. 4b), often resulting in SSWs and associated increases in poleward ozone transports. The Arctic temperature and ozone variability in the SCDM (Fig. 9f, j) is somewhat too low during early winter, consistent with a reduced stratospheric wave driving during this period (Fig. 4b). But during mid-winter, the Arctic ozone variability in the SCDM (Fig. 9j) is somewhat too high, perhaps related to the positive ozone bias seen in the lower stratosphere. There is also a too weak Arctic ozone variability during NH summer. Over Antarctica, the SCDM overall somewhat underestimates the temperature and ozone variability throughout the entire year (Fig. 9h, l), consistent with the negatively biased stratospheric wave driving over the SH (Fig. 4b). Another reason for the reduced variability over the SH is the much-simplified parameterization of heterogeneous ozone depletion."*

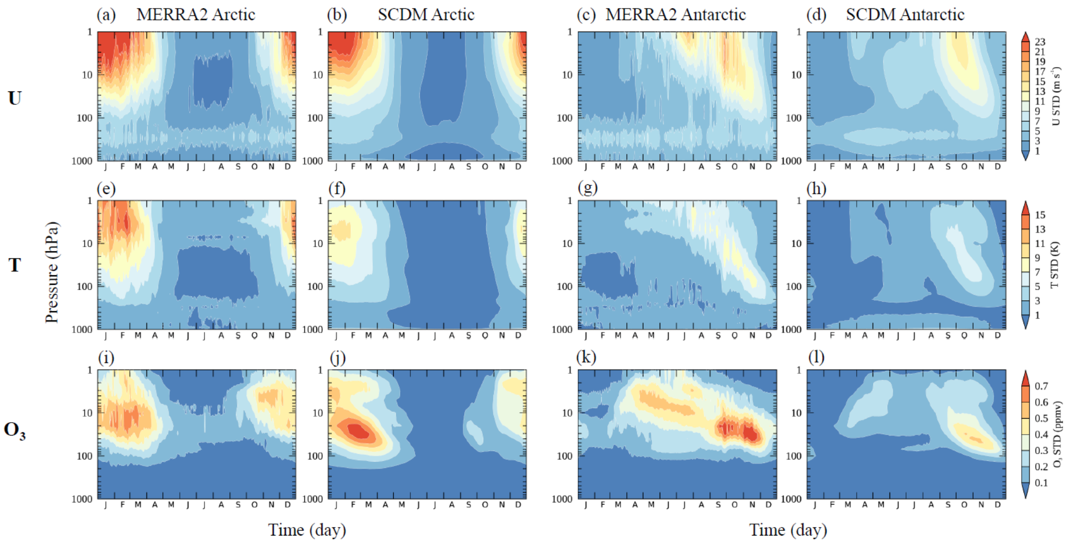

Figure. R4. Interannual variability of zonal-mean (a-d) zonal wind, (e-h) temperature, and (i-l) ozone. The interannual variability is estimated by standard deviation of T and O_3 over the Arctic (60ºN-90ºN) and the Antarctic (60ºS-90ºS) and by standard deviation of U at 60ºN and 60ºS. Results are shown for (a, c, e, g, i, k) MERRA2 and (b, d, f, h, j, l) SCDM.

Following up the above question, does interactive ozone improve the simulation of stratospheric dynamical variability in SCDM? In order to answer this question, an additional simulation without interactive ozone is required. If such simulation is available, I suggest adding a section to discuss this topic.

The related work for addressing the impact of interactive ozone is underway, but we very much prefer to publish the new outcomes in a more comprehensive separate paper. To give the reviewer some idea of the impacts of interactive ozone, we show in Fig. R1 the differences in the interannual variability of zonal-mean zonal wind and temperature from the two simulations. The first simulation is SCDM with interactive ozone, as described in the present manuscript, and the second simulation (PrO3) is from the SCDM but prescribing the climatological ozone from the first simulation. Fig. R1 shows that interactive ozone leads to significant increases in variability, mainly in April and May. The timing is to be expected since for ozone to have temperature effect, sun light is required.

Next, to understand whether interactive ozone influences the evolution of SSWs, we compare in Fig. R2 temperature composites of February SSWs. The difference between SCDM and PrO3 (panel c) suggests a more persistent temperature anomaly in the lower stratosphere when ozone is interactive. As said above, to achieve a more in-depth understanding for the role of interactive ozone, we already have and will perform further analysis, and we intend to publish the results in a separate paper. We now mention this in the conclusion of our manuscript at line 309, where we write:

L309: *"In upcoming work, we will use SCDM for an in-depth study of the role of interactive ozone for the variability of the coupled stratosphere-troposphere system and its associated feedbacks."*

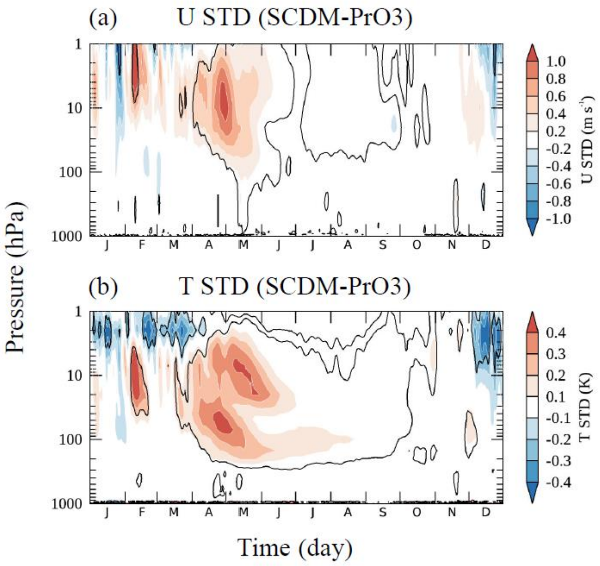

Figure. R1. Time-height cross-sections of the interannual variability for (a) zonal-mean zonal wind at 60ºN and (b) zonal-mean temperature averaged over 60ºN-90ºN. Shown are differences between the

SCDM run (interactive ozone) and the PrO3 run (prescribed three-dimensional ozone climatology from the SCDM run). Contours represent statistical significance of the difference at the 95% level using an F-test.

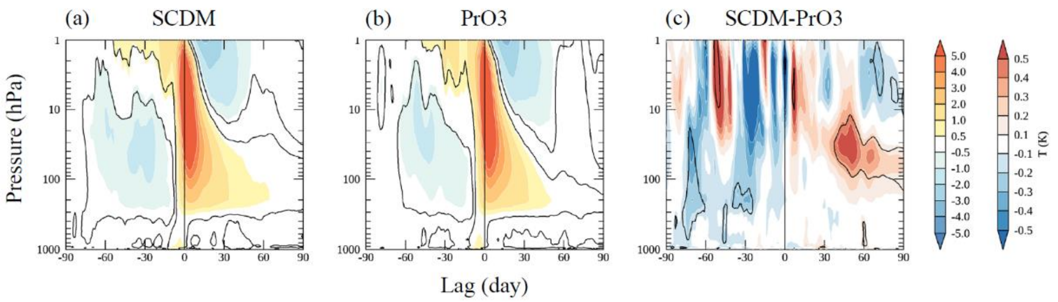

Figure. R2. February SSW composite for polar cap averaged (60ºN-90ºN) temperatures. Shown are results for (a) SCDM (interactive ozone), (b) PrO3 (prescribed ozone), and (c) SCDM-PrO3. Contours in (a) and (b) represent statistical significance of the anomaly at the 95% level using a two-tail Student t-test and in (c) indicate that the differences between SCDM and PrO3 are significant at the 95% level according to an F-test.

Line 310. I wonder what specific topics the authors plan to investigate (or have already investigated). And how do they plan to use the SCDM model to get a better understanding of these topics?

The main purpose of the SCDM is to study the role of interactive ozone for the variability of the coupled stratosphere-troposphere system and its associated feedbacks, especially for SSWs. As mentioned above, we address this by comparing two simulations using SCDM. The first simulation uses interactive ozone, and the second simulation uses a prescribed ozone climatology from the first simulation. We now mention this at line 310, where we write:

L310: *"We will conduct simulations with different ozone setups (e.g., interactive or fixed) to investigate how important interactive ozone is for the variability of the coupled stratosphere-troposphere system."*