Review of the paper

Implementation of solar UV and energetic particle precipitation within the LINOZ scheme in ICON-ART

by
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The paper documents the implementation of an upper boundary condition for NO_y (UBC-NO_y), and a linearized ozone parametrization (LINOZ) into the ICON-ART model. The LINOZ parametrization is further extended by terms describing ozone depletion by enhanced NO_y mixing rations. The UBC-NO_y allows to account for NO_y enhancements during periods of high energetic particle precipitation (EPP). Besides this, the spectral solar irradiance (SSI) variability with the 11-year solar cycle is considered, by providing LINOZ coefficient tables for solar maximum and solar minimum conditions which can be scaled with the F10.7 cm solar flux. The advantage of this modelling approach is its efficiency.

General comments

The paper describes a very efficient way to incorporate transient, time-dependent ozone to be used in long climate projection simulations with variable SSI and EPP forcing. After some minor changes, and some additional discussions, I recommend the publication in GMD.

The introduction lacks a discussion of alternative, existing options for effectively simulating transient ozone, such as the parameterization of *Cariolle and Teyssèdre* (2007), or SWIFT (*Wohltmann et al.*, 2017; *Kreyling et al.*, 2018)

The authors should discuss the possibility of using the model system for greenhouse gas scenarios. Is it possible to simulate realistic ozone concentrations with elevated GHGs using ICON-LINOZ?

The possibility of extreme scenarios, such as the CMIP 4xCO2 scenario, which was also discussed by *Meraner et al.* (2020) in connection with the parameterization of Cariolle, should also be discussed. Does the LINOZ parameterization work for such extreme CO_2 scenarios?

Specific comments

Line 91: *... by a joint developement between the German Weather Service (DWD) and ...*
Actually ICON is developed by the ICON partnership. Please replace with:
... by a joint development between the German Weather Service (DWD), the Max Planck Institute for Meteorology (MPI-M), Deutsches Klimarechenzentrum (DKRZ), the Karlsruhe Institute of Technology (KIT), and the Center for Climate Systems Modeling (C2SM) ...

Line 95: ICON has terrain following height levels only on the lower levels. They turn into levels at constant height levels.

Line 97: Which physics parametrizations are used? Later you refer to the ICON(NWP) physics package. This information should be given here already.

Lines 124 – 125: The differential equation needs more explanations. Which variables in the equation represent the tabulated coefficients? How many coefficients are included?

Lines 137–138: *... applied three model levels below the upper boundary. ...*
Reformulate:
... applied to the three uppermost model levels. ...

Line 166: You mention an upper atmosphere setup extending to 150 km. Is the model development described in this paper also tested and available for this upper atmosphere extension of ICON? If not, you should not mention the upper atmosphere extension here, as it is confusing.

Lines 195–196: *... where the UBC is applied three model levels below the top to avoid noise from the sponge layer. ...*
Please be more specific. Is the UBC applied at the three uppermost model levels, or at three levels starting at three levels below the model top? This is related to the comment to Lines 137–138.

Line 199: You describe the method to prescribe NO_y volume mixing ration (VMR), here. This should already be introduced in Section 2.3 (Lines starting at 137).

Lines 220–224: Some details about the use of variable SSI are missing. For example, the number of bands used in the photochemical box model. A somewhat more detailed description of the method of *Hsu and Prather* (2010) Hsu and Prather (2010) is also missing, instead of referring to the reference.

The preparation of the SSI data is better described by the term integration rather than the term interpolation.

Line 275: You write: *. . . linked to an Enhanced Stratospheric (ES) event . . .*
Probably you meant Elevated Stratopause (ES) events.

Figure 8: Please adapt the contour level interval (0.3, or 0.5 %) of the shading, to better match the range of the data.

Technical corrections

Line 103: *Tras . . .* replace with: *Trace . . .*

Line 107: *. . . in which a tracer has a fixed lifetime for depletion, is considered . . .*
reformulate:
. . . considering a tracer with a fixed lifetime for depletion . . .

Line 109: *- And, full . . .*
replace with:
- and a full . . .

Line 153: *. . . Linoz . . .*
Please use consistently in the paper:
. . . LINOZ . . .

Line 174: *Three model experiment . . .*
Add an 's' *. . . experiments . . .*

Line 189: please change *. . . derived from both simplified parametrization scheme . . .*
to *. . . derived from both, a simplified parametrization scheme . . .*

Figure 1: You should add labels for the experiments on top of each column.

Lines 226–227: change *. . . and applied a linear interpolation based on the solar activity index. F10.7 between these two states within the model. . . .*
to *. . . and applied a linear interpolation based on the F10.7 solar activity index between these two states within the model. . . .*

Lines 228–230: reformulate these sentences: *. . . we conducted percentage difference between SOLMAX and UBC-NOy experiments relative to SOLMAX experiment. SOLMAX experiments is with the solar UV radiation fixed at its maximum, using climatologies calculated based on the solar maximum spectrum only.*
This is what I understand from the explanation. Correct, if this is a misunderstanding:
. . . we calculated the percentage difference between the SOLMAX and UBC-NOy ex-

periments relative to the SOLMAX experiment. The SOLMAX experiment uses the solar UV radiation fixed at its maximum, resulting in climatologies calculated based on the solar maximum spectrum only.

Figure 2: Caption, please change ... *Impact of SSI on ozone* ...
to ... *Impact of SSI changes on ozone* ...

Line 253: Better decribe what is shown in Figure 5. E.g.:
In Figure 5, EPP-NOy in ICON-ART, shown as the differences between the UBC-NO_y and the BASE simulations, is compared to EMAC and MIPAS/ENVISAT v8.

Line 258: correct ... *leds* ... to ... *leads* ...

Lines 260–261: write ... *Comparison against the EMAC model* ...

Bibliography

Cariolle, D., and H. Teyssèdre (2007), A revised linear ozone photochemistry parameterization for use in transport and general circulation models: multi-annual simulations, *Atmospheric Chemistry and Physics*, *7*, 2183–2196, doi:10.5194/acp-7-2183-2007.

Hsu, J., and M. J. Prather (2010), Global long-lived chemical modes excited in a 3-d chemistry transport model: Stratospheric n2o, noy, o3 and ch 4 chemistry, *Geophysical Research Letters*, *37*, doi:10.1029/2009GL042243.

Kreyling, D., I. Wohltmann, R. Lehmann, and M. Rex (2018), The extrapolar swift model (version 1.0): fast stratospheric ozone chemistry for global climate models, *Geoscientific Model Development*, *11*, 753–769, doi:10.5194/gmd-11-753-2018.

Meraner, K., S. Rast, and H. Schmidt (2020), How useful is a linear ozone parameterization for global climate modeling?, *Journal of Advances in Modeling Earth Systems*, *12*, 1–19, doi:10.1029/2019MS002003.

Wohltmann, I., R. Lehmann, and M. Rex (2017), Update of the polar swift model for polar stratospheric ozone loss (polar swift version 2), *Geoscientific Model Development*, *10*, 2671–2689, doi:10.5194/gmd-10-2671-2017.