Project: 519

Project title: NATHAN - Quantification of Natural Climate Variability in the Atmosphere-Hydrosphere System with Data Constrained Simulations

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Preface

The work of the former Helmholtz-University Young Investigators Group NATHAN (funding finished end of 2015) has been continued within the national BMBF-ROMIC SOLIC project (Quantification of Uncertainties of SOLar Induced Climate variability) until 2017. In 2018/2019 we continued to address questions related to the overall topic of solar induced natural climate variability financed through GEOMAR base funding. After a massive delay the BMBF project "Solar contribution to climate change on decadal to centennial timescales (SOLCHECK)" finally started in December 2019.

Model simulations in 2020

As part of the BMBF project SOLCHECK we implemented the parameterization of reactive nitrogen produced by energetic particle precipitation (EPP) down to the lower stratosphere developed by Funke et al., 2016 into GEOMAR's climate modelling system FOCI (Matthes et al., 2020). In most of the runs (SW132 to SW143, see table below) the algorithm to detect elevated stratopause events (ESEs) is used. A realistic representation of EPP and ESEs leads to a more realistic representation of reactive nitrogen in the stratosphere and above which in turn affects concentrations of stratospheric ozone with possible implications on climate down to the surface.

Experiment ID	Years	Configuration
SW127	1850 - 2067	historical/future simulation (SSP585 scenario) to validate the newly implemented EPP parameterization in FOCI
SW132	1850 - 2013	Same as above but with implementation of detection of elevated stratopause events
SW133	1850 - 2013	2nd ensemble for SW132
SW142	1850 - 2013	Same as SW132 but with solar forcing kept at pre-industrial levels.
SW143	1850 - 2013	2nd ensemble for SW142

Table 1: Overview of simulations performed in 2020

Results

As a first step towards our work planned in SOLCHECK we validated the implementation of the ESE and EPP parameterization in FOCI. Here we found the annual occurrence frequency of major sudden stratospheric warmings (SSWs) averaged over the four historical simulations (SW132 to SW143) is 0.49, which is comparable to the frequencies for the EAR40 (0.52). The average annual occurrence frequency of ESEs is 0.26, a bit smaller than the MERRA (0.31 for 1979–2011). The EPP related to the geomagnetic activity can directly produce NOy in the upper mesosphere (0.03hPa), which is modulated by the solar activity at decadal timescales (not shown). Descent of the EPP-NOy downward in the polar winter especially after the SSW/ESEs leads to O3 depletion in the stratosphere. This so-called EPP indirect effect can be reasonably captured by FOCI, as shown in Figure1 below. The volume mixing ratio of NOy increases due to the very large solar proton events in 2004 and 2005, the odd EPP-NOy descends down to the stratosphere (a) and induces stratospheric O3 depletion in these two years (b). Both the major SSWs and ESEs in 2004 and 2005 are detectable in FOCI. Detailed analysis of EPP response in the upper atmosphere and the associated solar-climate connections is currently underway and will be put on more solid ground using the additional experiments that will be performed in 2021.

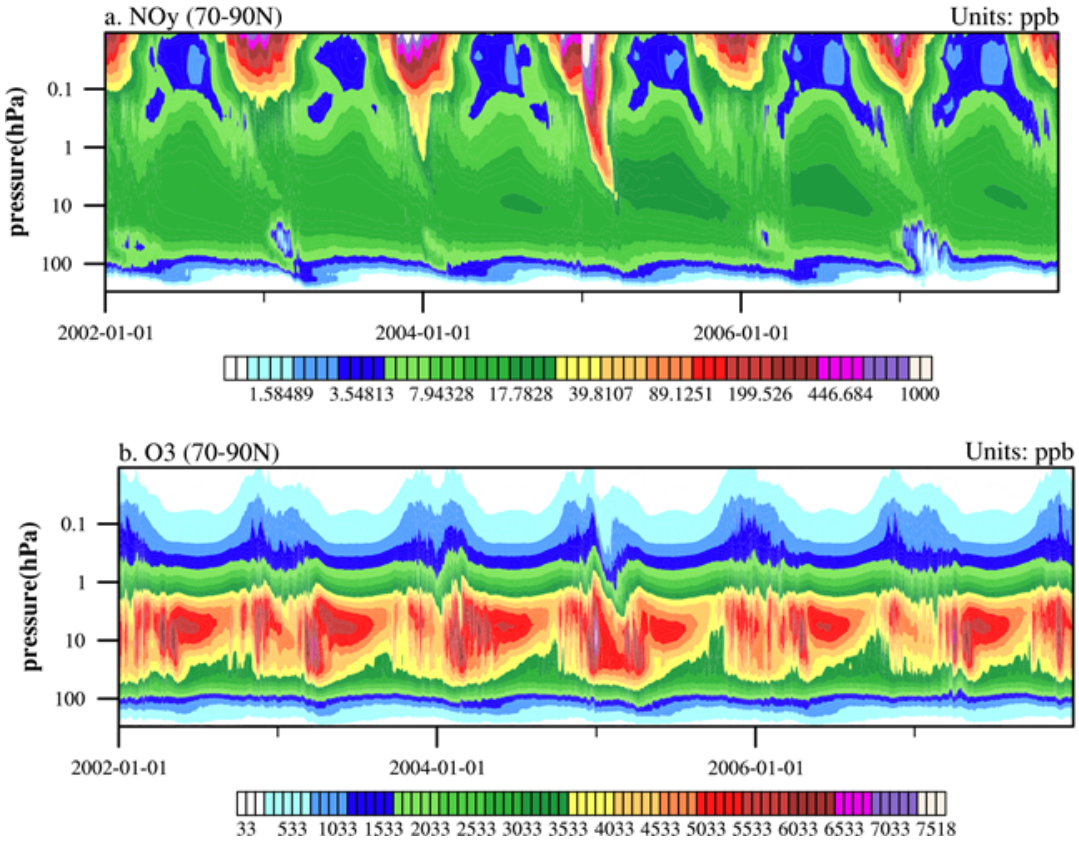

Figure 1. Temporal evolution of daily volume mixing ratio of (a) NOy and (b) O3 averaged over the high latitudes (70N-90N) from 2002 to 2008.

References

Funke, B., Lopez-Puertas, M., Stiller, G. P., Versick, S., & Von Clarmann, T. (2016). A semi-empirical model for mesospheric and stratospheric NOy produced by energetic particle precipitation. *Atmospheric Chemistry and Physics*, *16*(13), 8667–8693. https://doi.org/10.5194/acp-16-8667-2016

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