Study of factors influencing polar ozone using CCM SOCOLv3: solution of the problem with difference from satellite data

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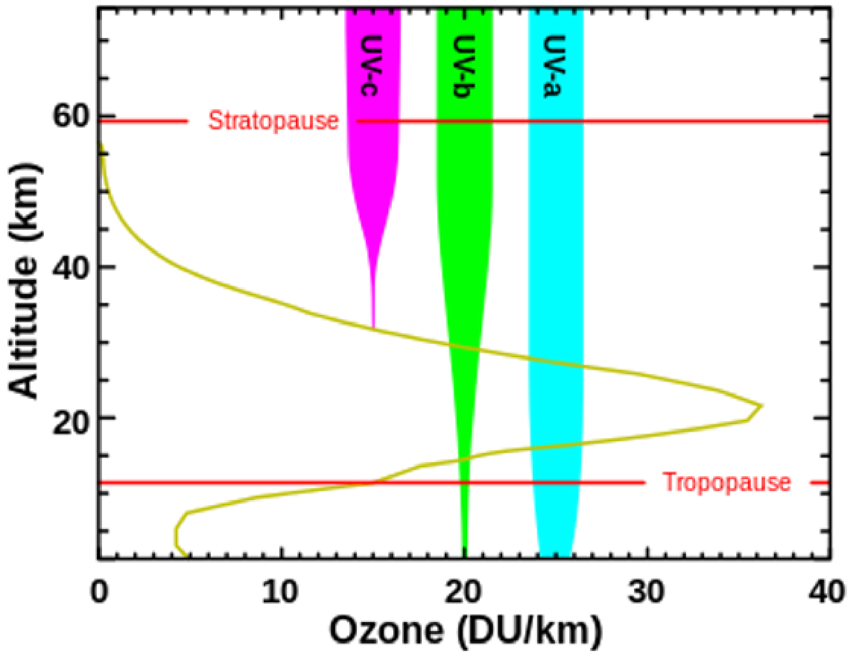
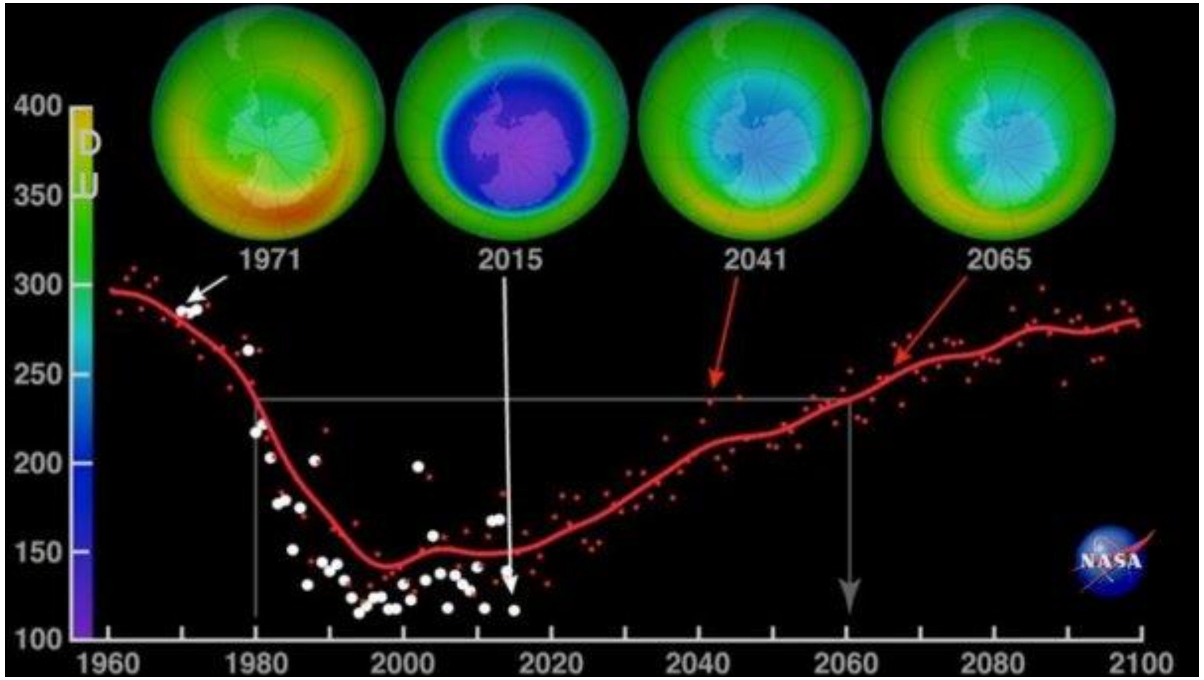
Introduction



Absorption of ultraviolet radiation by the ozone layer.

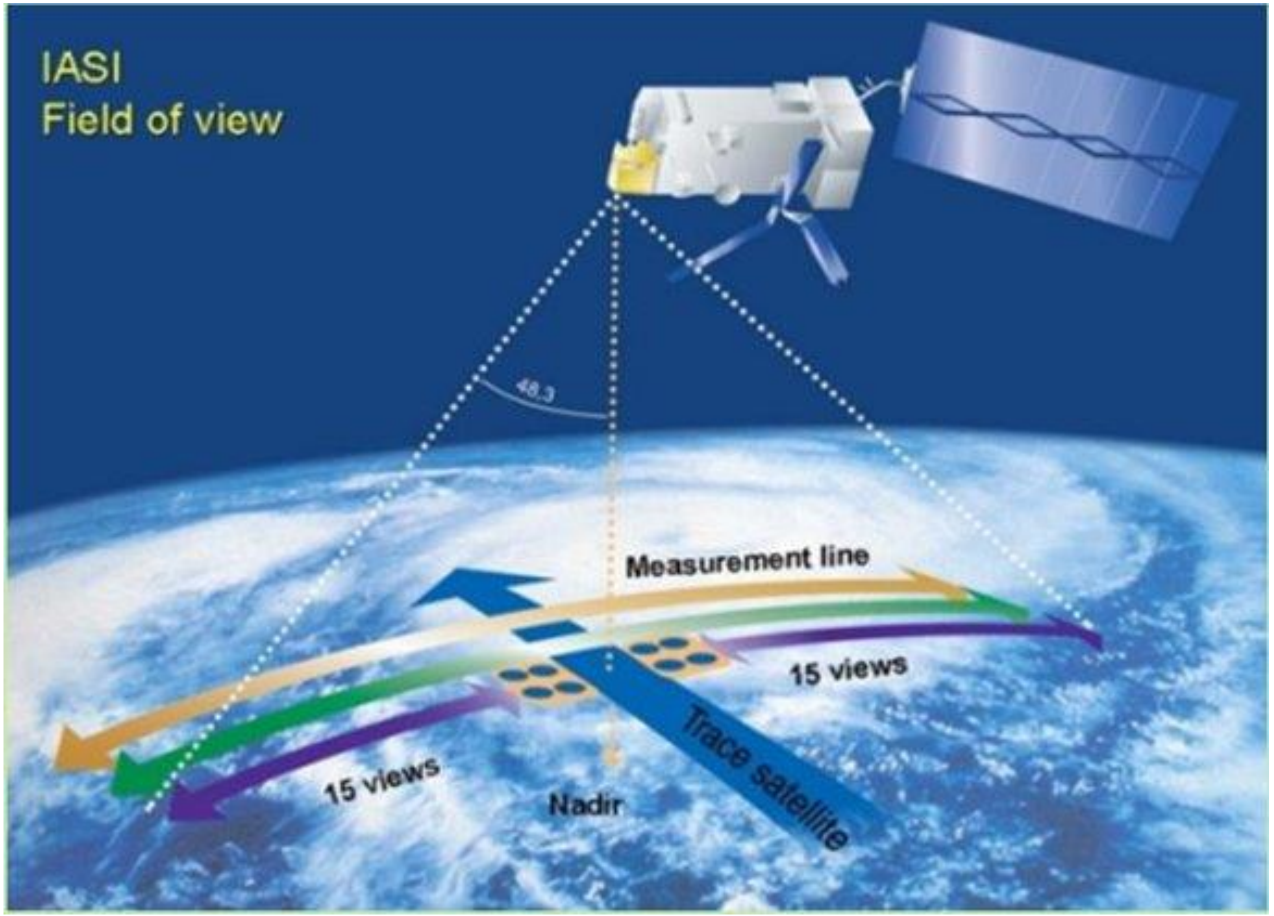


Dynamics of total column ozone

Introduction

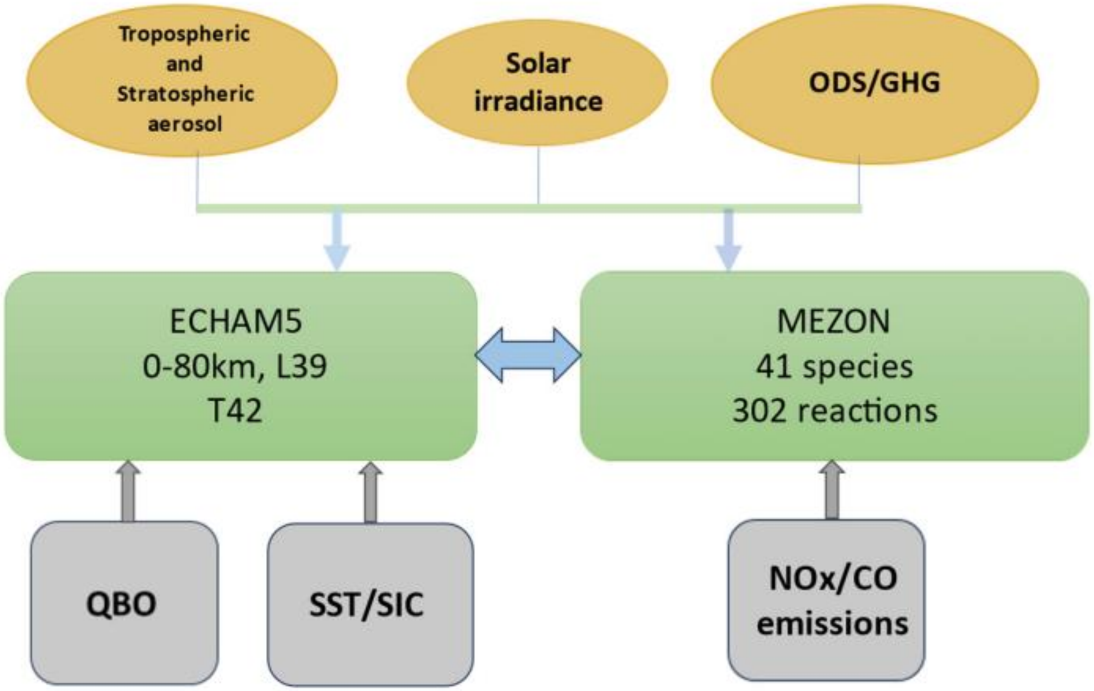
IASI - Infrared Atmospheric Sounding Interferometer

- IASI measures infrared radiation with a horizontal resolution of 12 km over a swath width of about 2200 km
- Optical interferometry allows to obtain accurate values of infrared radiation (3.4-15.5 microns)
- Total column ozone measurements can be realized under polar night conditions with relative error of 5%



Introduction

SOCOLv3

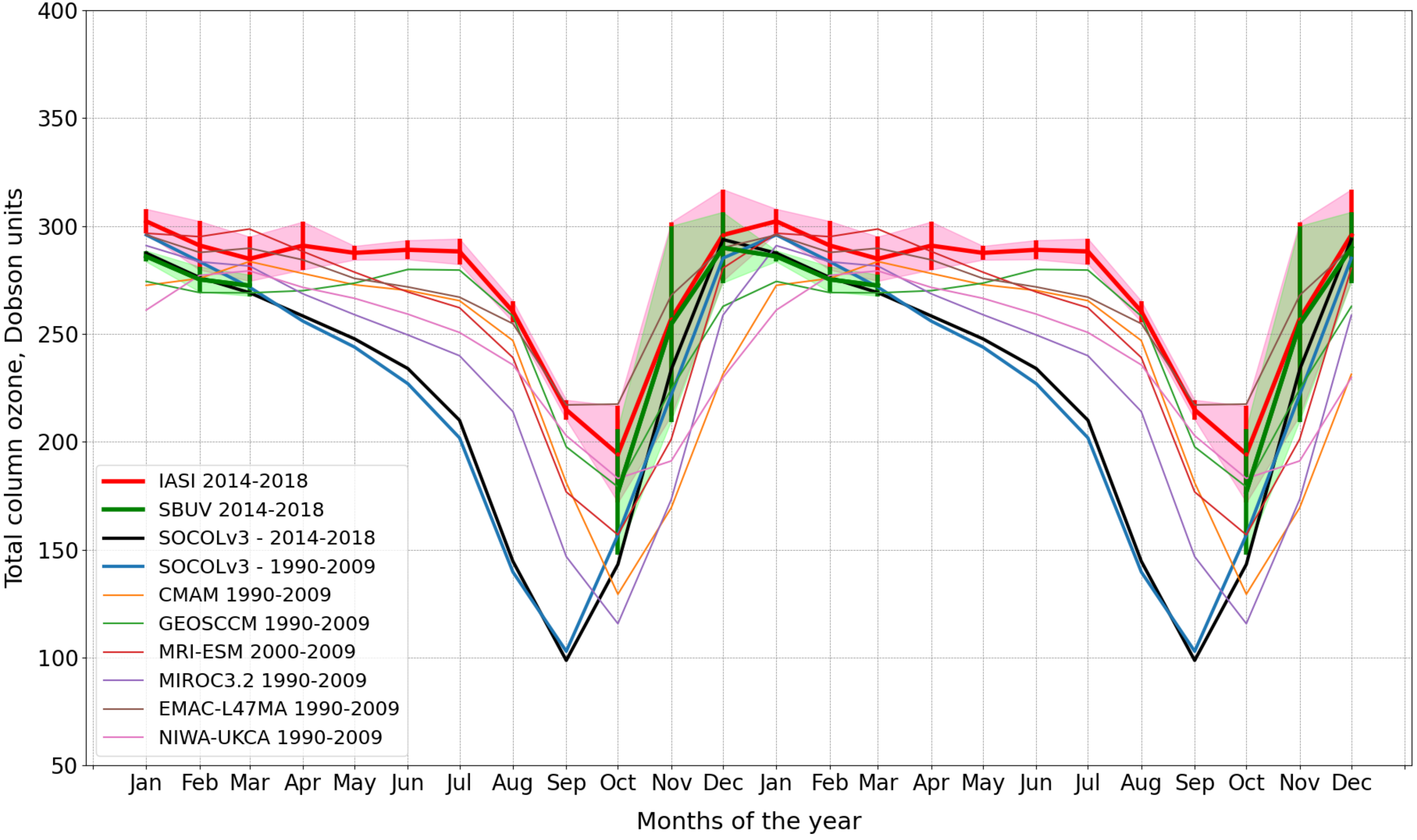


- Chemistry-climate model SOCOLv3 consists of the general circulation model (GCM) of the middle atmosphere ECHAM5 and the chemical module (CM) MEZON.

GCM and CM are interactively linked by 3D fields of temperature, winds (from GCM to CM), and radiatively active species (from CM to GCM).

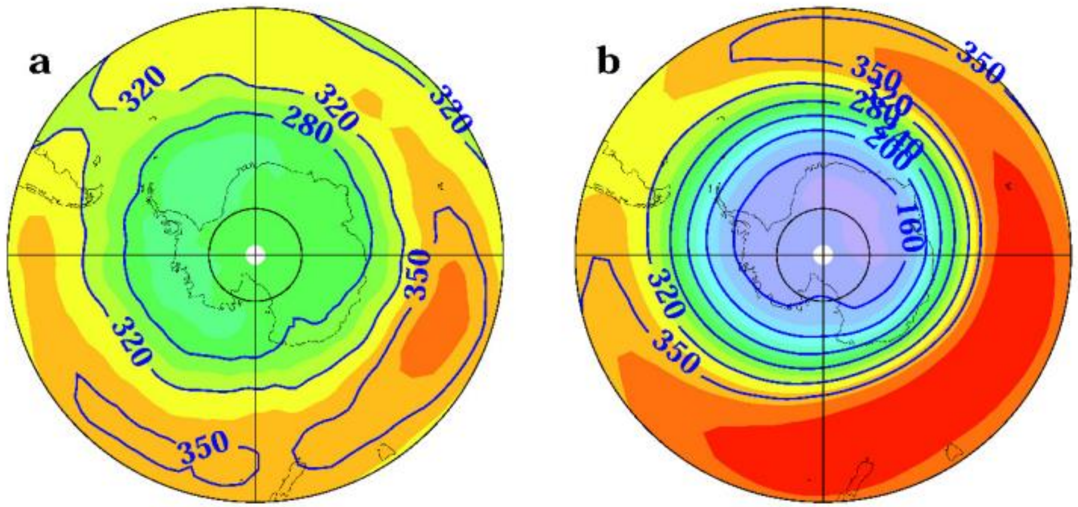
- The SOCOLv3 has 39 vertical levels (from the surface up to 0.01 hPa), horizontal resolution T42 – 2,8125°
- The model includes 41 chemical elements. Interactions between gas species are determined by 140 gas phase reactions, 46 photolysis reactions, and 16 heterogeneous reactions on liquid sulfate aerosols and solid particles of H_2O and HNO3·3H2O.

Problem



Total column ozone, Dobson units
400
350
300
250
200
150
100
50
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Months of the year
IASI 2014-2018
SBUV 2014-2018
SOCOLv3 - 2014-2018
SOCOLv3 - 1990-2009
CMAM 1990-2009
GEOSCCM 1990-2009
MRI-ESM 2000-2009
MIROC3.2 1990-2009
EMAC-L47MA 1990-2009
NIWA-UKCA 1990-2009

Problem



The TCO (DU) averaged over all Augusts during
the 2014-2018 period from IASI data (a), reference run (b)

The figure reveals that the model heavily underestimated the TCO values over the polar region of the SH against the satellite data.

In August the difference can exceed 100 DU.

Main processes

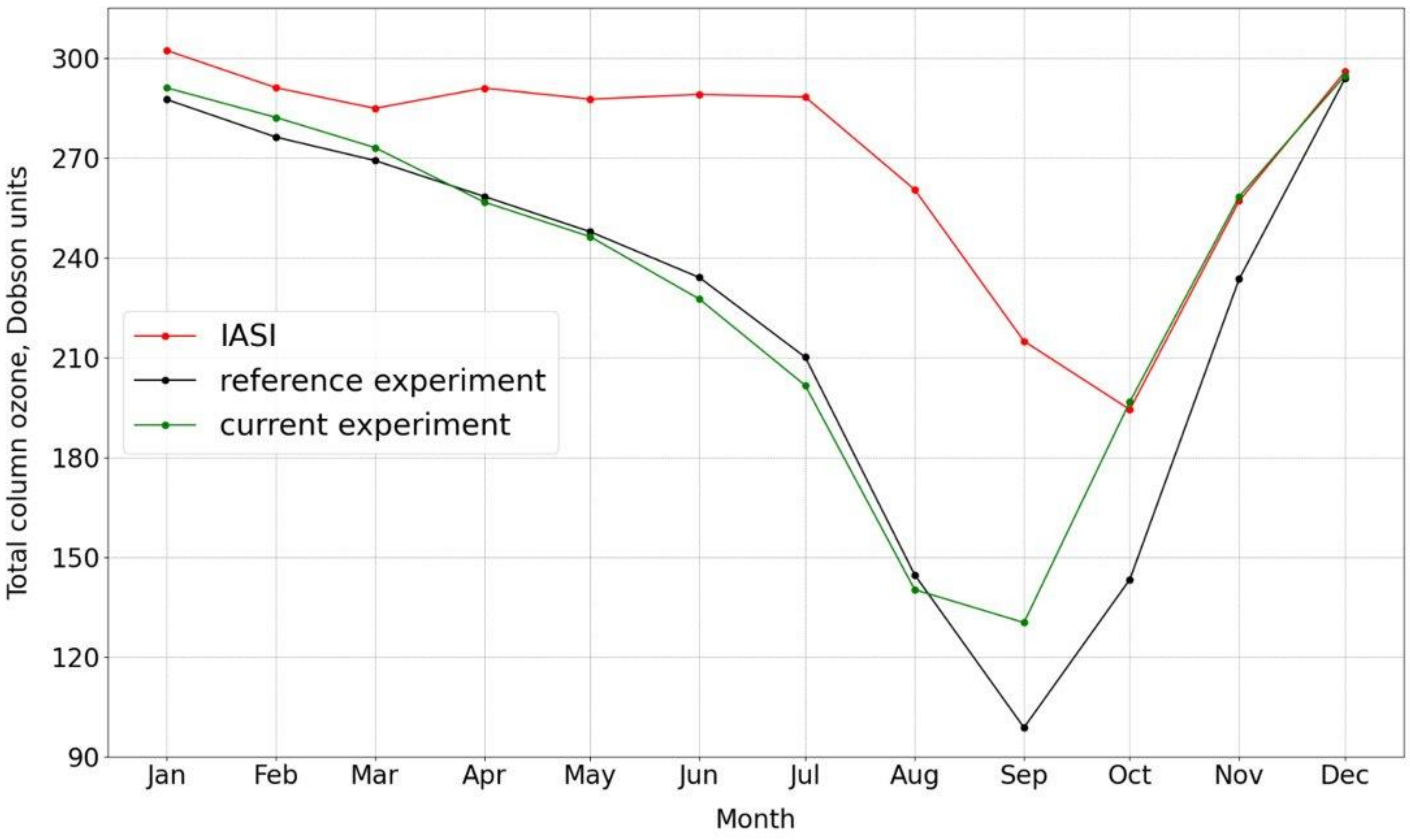
• The ozone content in the winter polar stratosphere is controlled mainly by:

- Heterogeneous reactions;
- Photodissociation of ozone and other species by solar radiation at the large zenith angles of Sun (Brasseur and Solomon, 2005);
- The transport of the species into the polar night vortex area by the sub-grid scale motions (Shuhua et al., 2002).

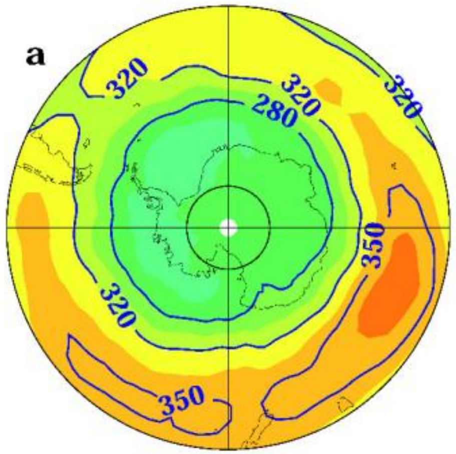
Results: Heterogeneous chemistry run

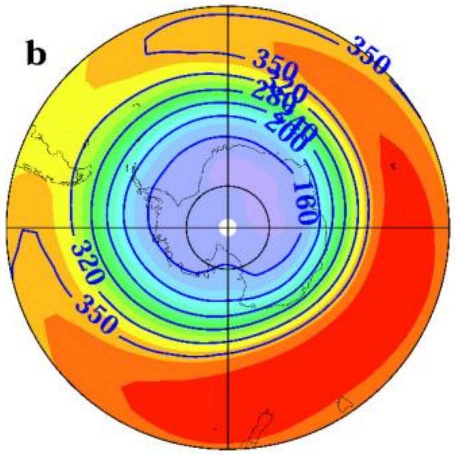
Model run with a twice decreased rate of the heterogenies reaction

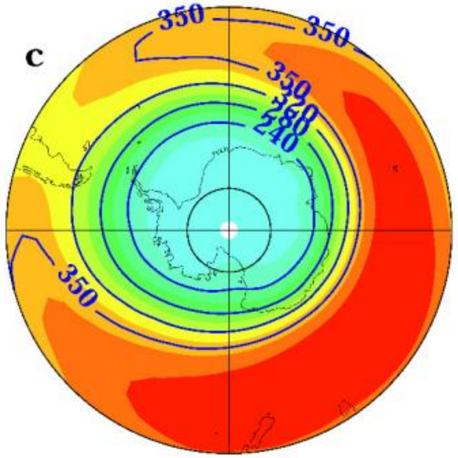
$HCl + ClONO_2 \rightarrow Cl_2 + HNO_3$ (· 0,5)



Results: Reduced photodissociation of O_3 run





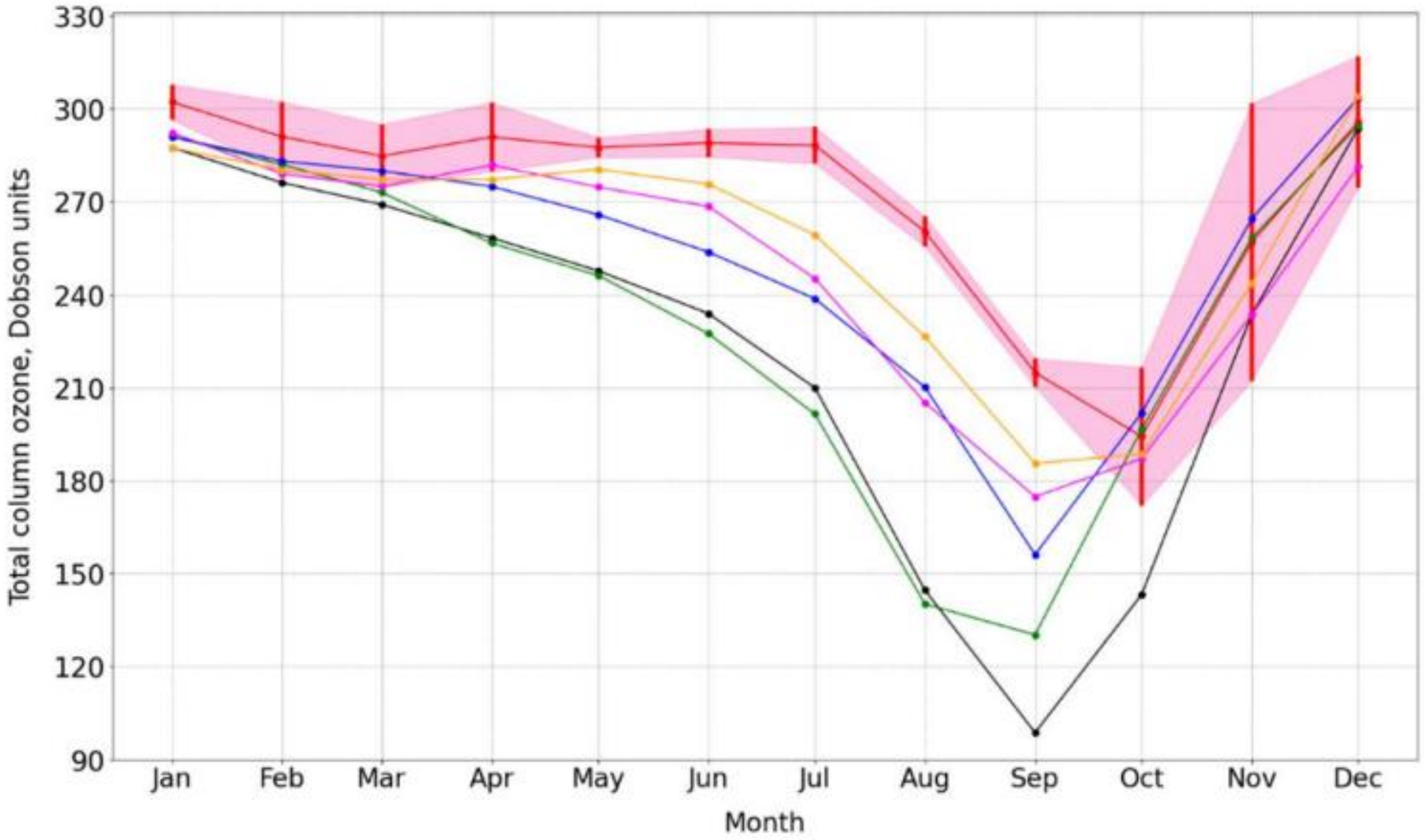


The TCO (DU) averaged over all Augusts during the 2014-2018 period from a) IASI data, b) reference run and c) reduced photodissociation of O_3 run.

The current run leads to much better agreement between modeled and observed TCO inside the vortex area but deteriorate TCO in the middle and high latitudes from July to November and leads to TCO enhancement in comparison with IASI measurements.

Results: Reduced photodissociation of O_3 run

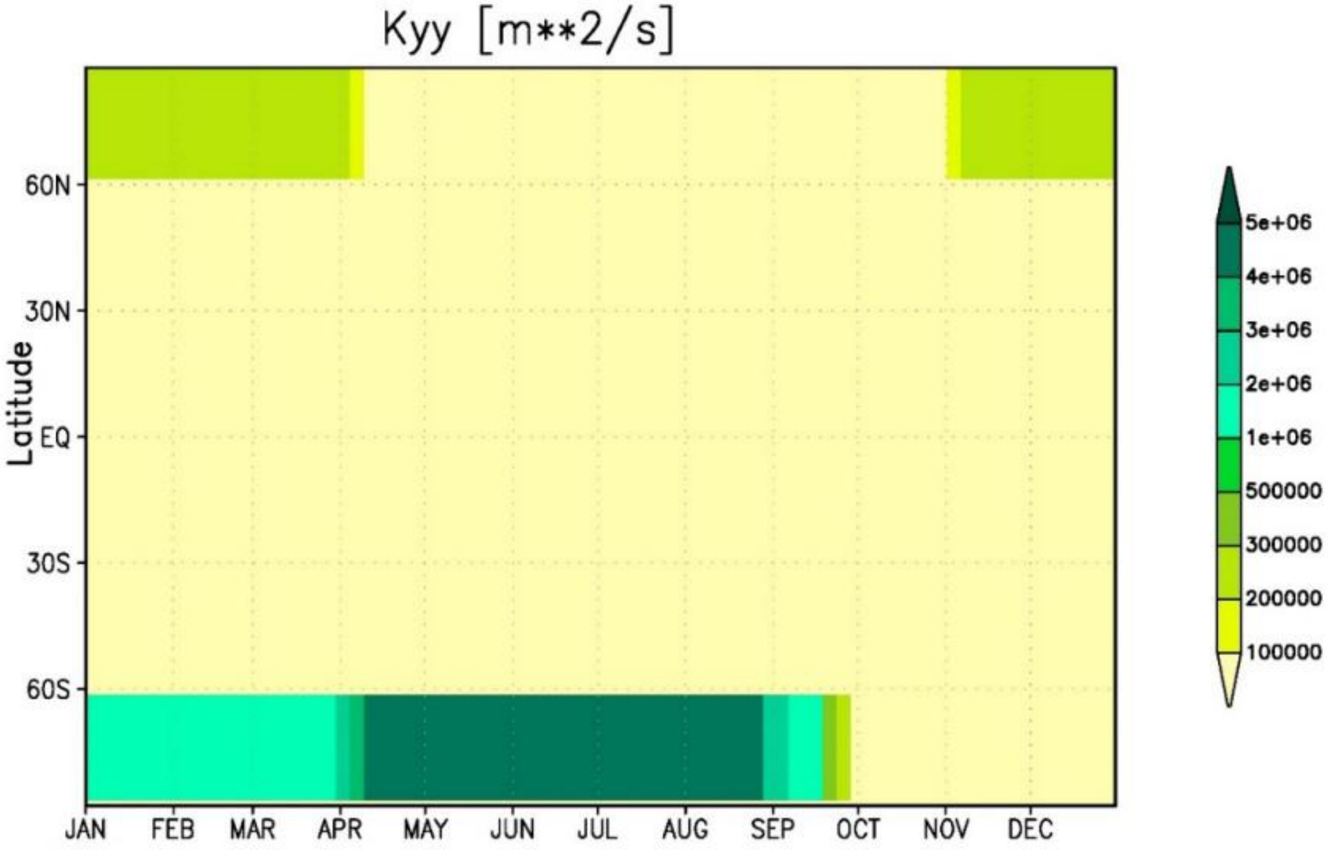
Name	Description
SR1	The 2 times reduction of the heterogenies reaction rate.
SR2	The 4 times reduction of the ozone photodissociation rates.
SR3	Including the horizontal mixing of all transported species into the SH polar vortex
SR4	SR2+SR3



TCO (DU) averaged over 2014-2018, at the 80°S as the IASI measurements (red) and the results of the reference (black), SR1 (green), SR2 (blue), SR3 (magenta), and SR4 (yellow) experiments.

Results: Model run with the subgrid-scale mixing

According to the Prandl mixing length theory the maximum values of K_{yy} can be estimated as $< 6 \cdot 10^6$ m^2/s



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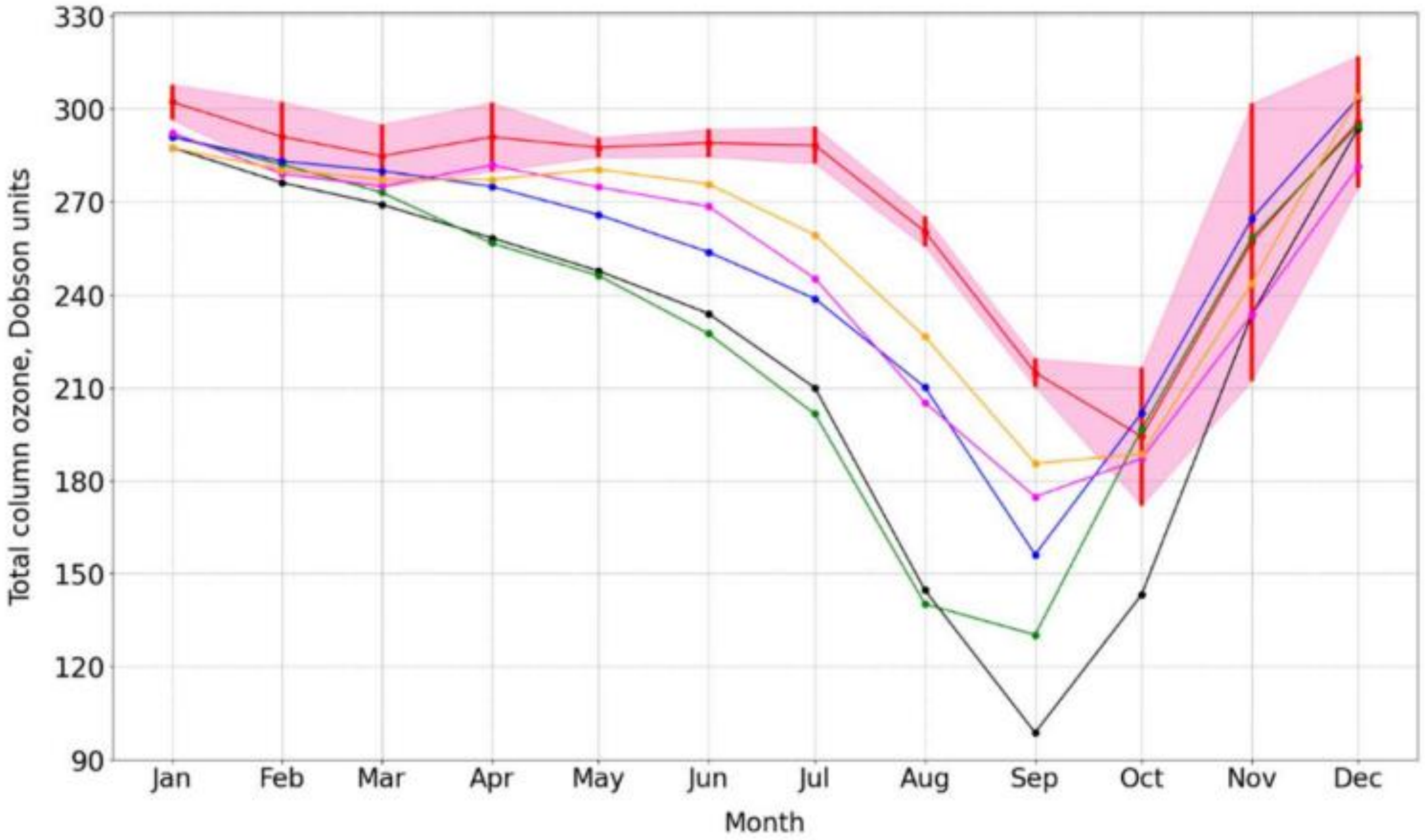
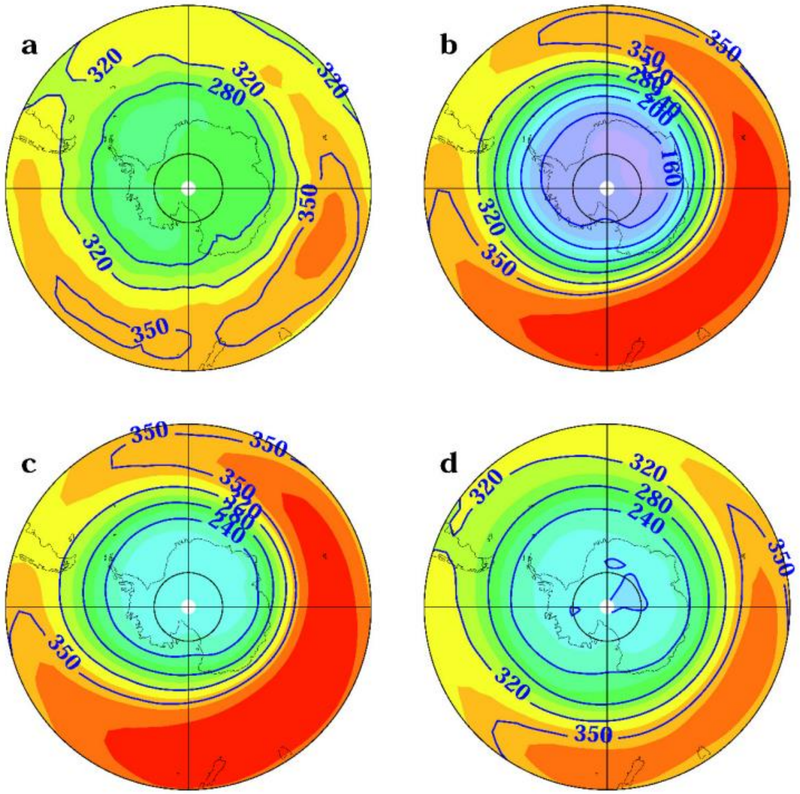
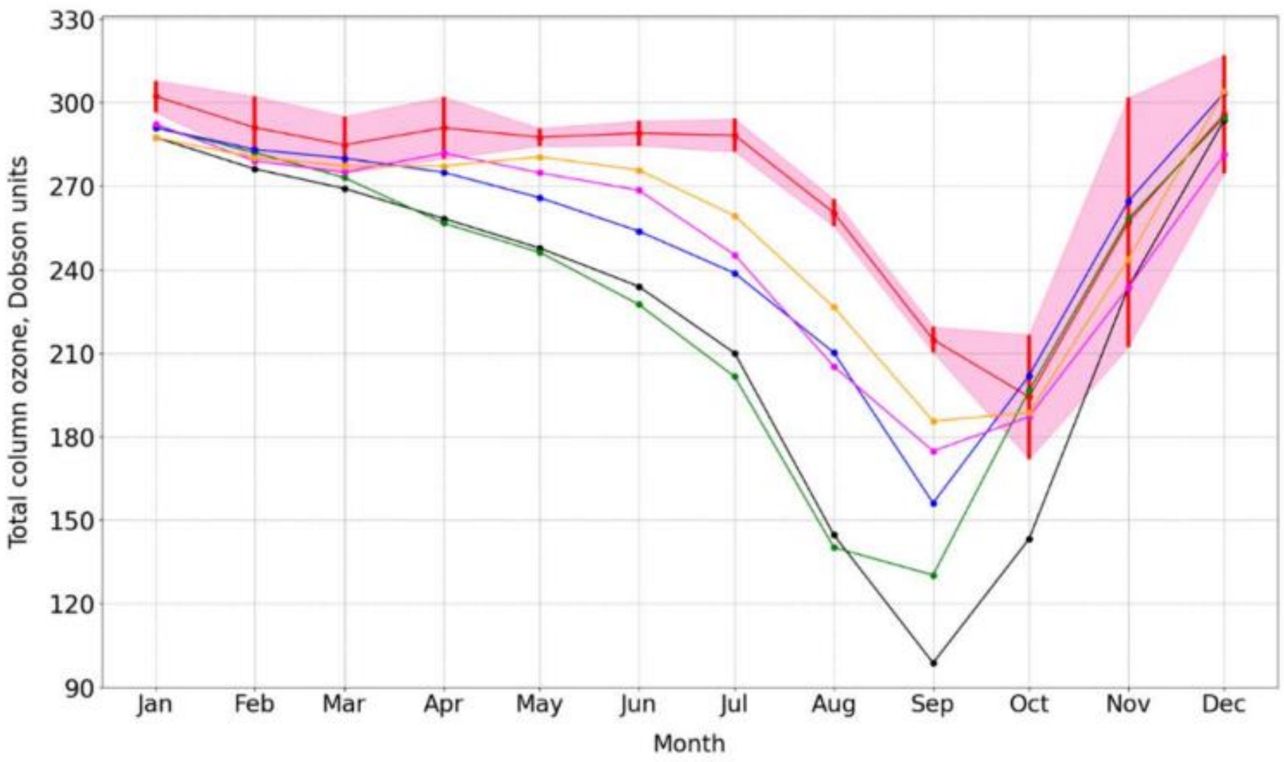


TCO (DU) averaged over 2014-2018, at the 80°S as the IASI measurements (red) and the results of the reference (black), SR1 (green), SR2 (blue), SR3 (magenta), and SR4 (orange) experiments.

Results: Model run with extra mixing and weaker photolysis

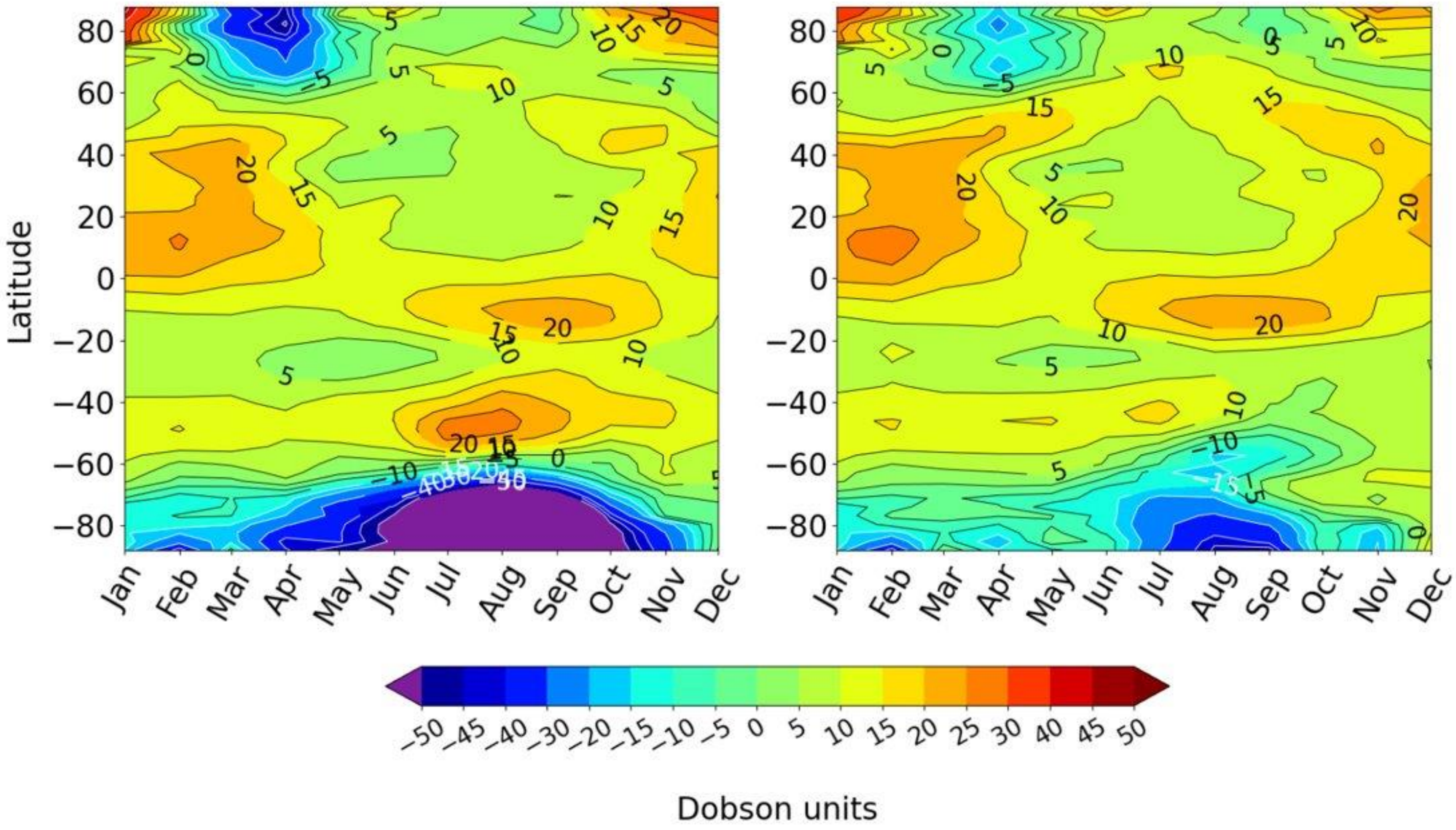


The TCO (DU) averaged over all Augusts during the 2014-2018 period from a) IASI data and d) current experiment



TCO (DU) averaged over 2014-2018, at the 80°S as the IASI measurements (red) and current (yellow) experiments.

Results: Model run with extra mixing and weaker photolysis



Conclusion

1. Three parameters affecting polar ozone were studied using SOCOLv3:

   (1) heterogeneous chemistry reaction rates,

   (2) photodissociation intensity and (3) meridional horizontal transport.

2. Comparison of the total column ozone (TCO) in model experiments with IASI (2014-2018) showed that the model TCO is most sensitive to processes (2) and (3).

3. Correction of the O3 photolysis rate and tuning of the meridional sub-grid mixing (into the polar vortexes) made it possible to fix a significant overall transport of SOCOLv3 ozone into the polar region of the southern hemisphere.

4. The proposed increase of the horizontal mixing can be recommended for the CCMs with relatively low (more than 1 deg) horizontal resolution.