Ozone variability near Saint Petersburg, Russia: Analysis of experimental and simulated time series (2000-2015)

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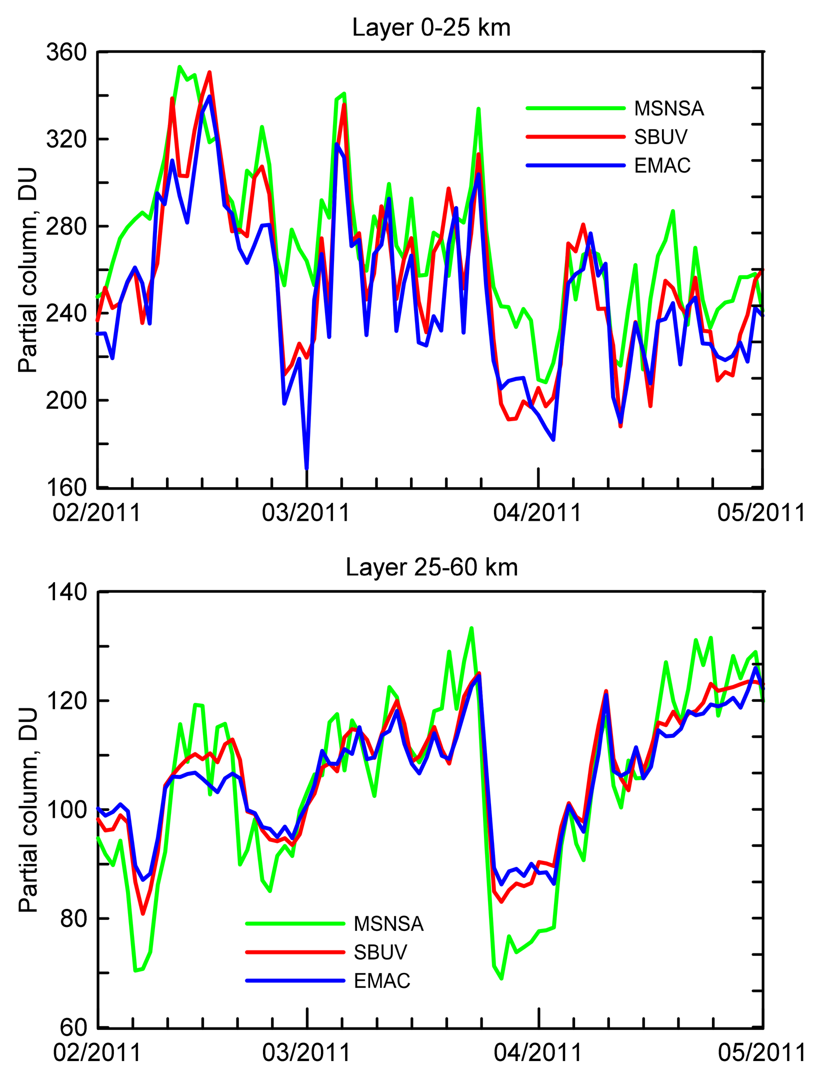
ABSTRACT

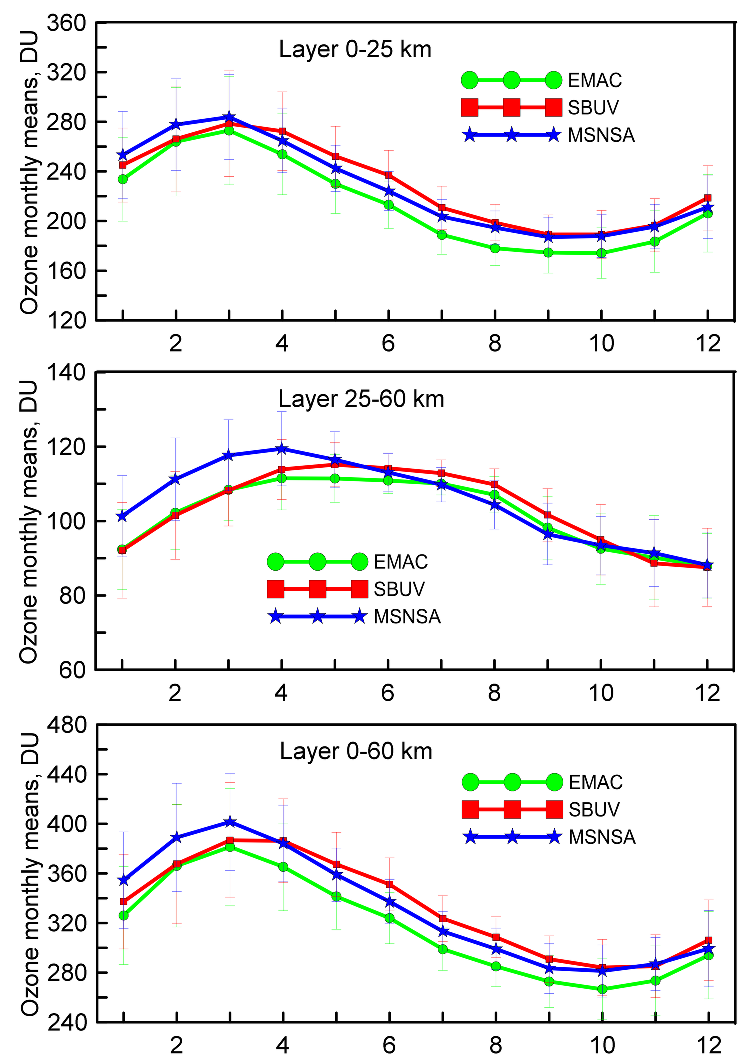
The location of Saint Petersburg (60N, 30E) near the border of mid and high latitudes allows observing the ozone changes under different atmospheric conditions, including polar vortex intrusion. We collected datasets of SBUV satellite ozone observations in the whole atmosphere and in the two atmospheric layers 0-25 km and 25-60 km for the period between 2000 and 2015. Moreover, we got the ozone numerical simulations by the chemistry climate model (CCM) - the ECHAM5/MESSy for Atmospheric Chemistry model [1] and the chemistry transport model (CTM) – the model MSNSA of low and middle atmosphere, which is based on the MERRA wind, temperature, pressure and humidity reanalysis [2]. The validation of CCM and CTM in comparison with experimental data is very important for improving models, which can simulate the spatial and temporal variations of gas composition as well as predict the future climate changes.

We analysed the time series of daily averaged ozone total and partial columns as well as of corresponding monthly averages. Generally, the statistical characteristics of the comparison (means, variations, correlations, etc.) demonstrate a high level of agreement between experimental and numerical datasets. However, we observe some systematic differences, e.g. models overestimate the ozone values in the late winter – early spring periods. In some cases, models experience strong high-frequency oscillations of ozone content, which may or may not be observed in the satellite measurements. Especially, we paid much attention to the quality of models in the periods of significant ozone loss over polar and subpolar regions. Additionally, we applied the Fourier analysis to experimental and simulated time series for better understanding the observed seasonal changes in ozone columns and the discrepancy between models and measurements.

Comparison of the measured and simulated ozone column data



The sensitivity of the models to the rapid ozone loss



Monthly averages for the 2000-2015 period

Time series of SBUV measurements (v.8.6 MOD) are available from early 1970 with a number of time gaps [3]. For this analysis, we used SBUV measurements from 2000 up to 2015 (NOAA19 satellite), overpasses near St. Petersburg, Russia. EMAC simulations (every hour) are available from 2000 up to 2015. As SBUV usually measures at 10-11 UT, we averaged FTIR measurements between 6 and 14 UT and EMAC simulations between 8-14 UT. MSNSA data are daily averaged.

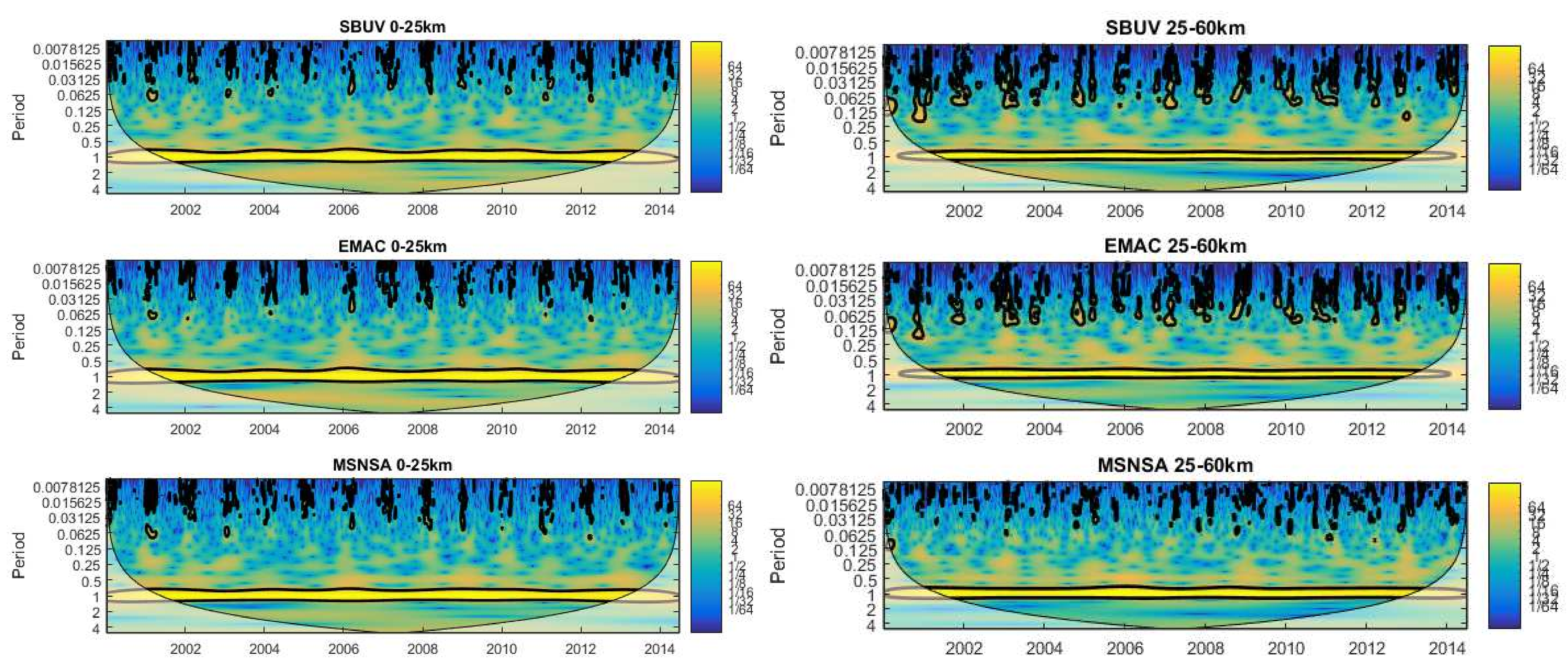
Differences between SBUV ozone measurements and numerical simulations (2000-2015)

Dataset	0-60 km			0-25 km			25-60 km		
	Difference		R	Difference		R	Difference		R
	DU	%		DU	%		DU	%	
EMAC	16 ± 16	5 ± 5	0.946±0.001	15 ± 15	7 ± 7	0.938±0.002	1 ± 4	1 ± 4	0.959±0.001
MSNSA	0 ± 23	0 ± 7	0.893±0.003	2 ± 20	1 ± 9	0.883±0.003	-2 ± 8	-2 ± 8	0.820±0.005

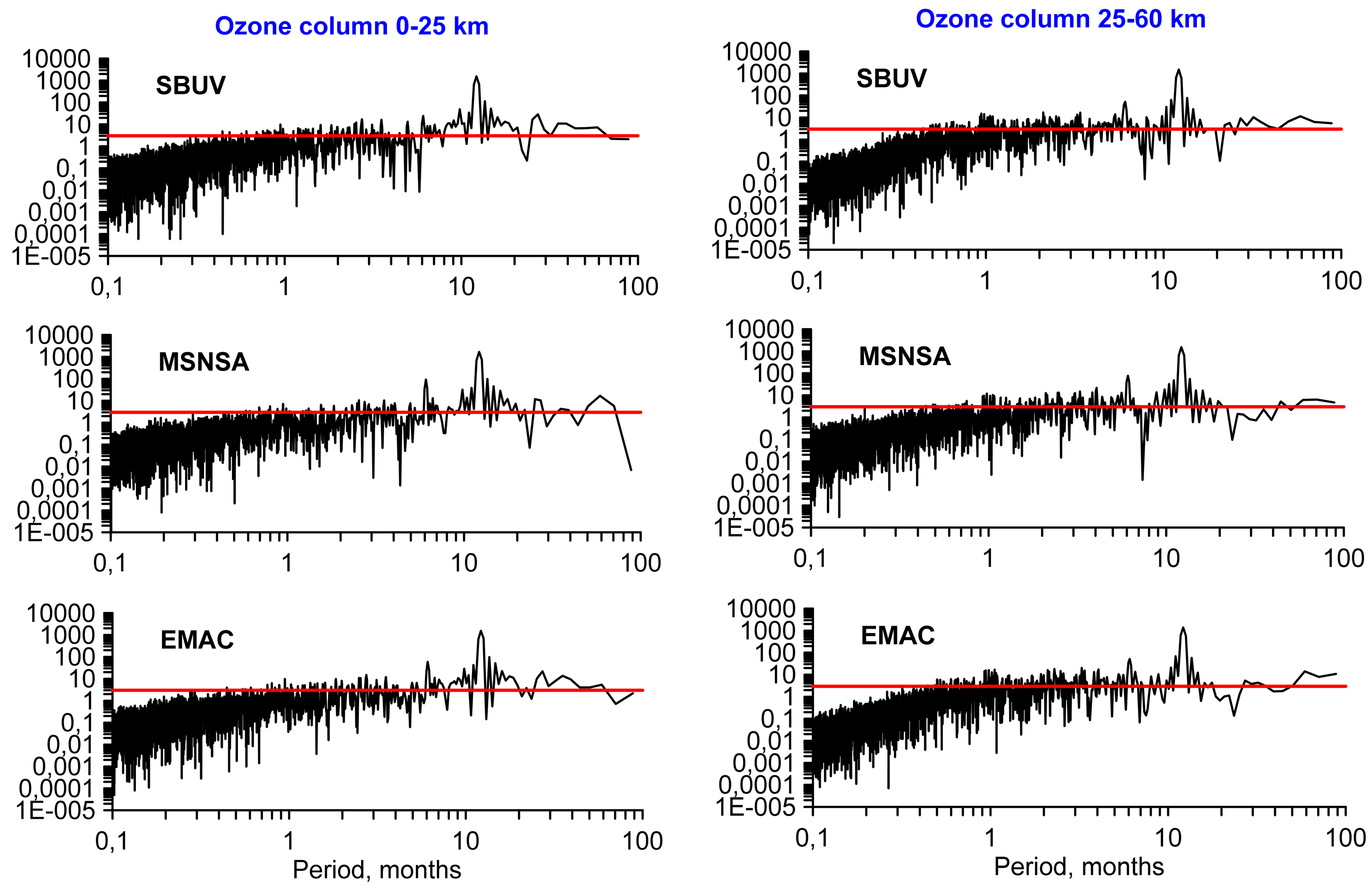
Ozone columns trends estimations (2000-2015)

Dataset	0-25 km		25-60 km		0-60 km	
	DU / year	% / decade	DU / year	% / decade	DU / year	% / decade
SBUV	-0.39±0.24	-1.68±1.03	+0.22±0.07	+2.1±0.7	-0.17±0.27	-0.51±0.81
EMAC	-0.17±0.24	-0.77±1.11	+0.06±0.07	+0.60±0.63	-0.11±0.28	-0.33±0.85
MSNSA	-0.11±0.23	-0.50±1.01	+0.06±0.08	+0.57±0.72	-0.05±0.28	-0.16±.085

Fourier and wavelet analysis



In general, the both models are well agreed with the SBUV measurements.
In 0-25 km layer, the six-month oscillations are more sharped in simulations than in measurements.
In 25-60 km layer, the atmospheric Rossby waves are well reproduced by the EMAC model, whereas the wavelet spectrum of the MSNSA model is in a good agreement with that of the measurements only in 0-25 km layer.



Normalized power spectral density of the ozone columns time series (red line relates to the 95% confidence interval)

Conclusions

The comparison of the numerical (EMAC and MSNSA) and the measured (SBUV) time series of the ozone columns in two atmospheric layers near St. Petersburg demonstrates their good agreement in general.

The EMAC simulation slightly underestimates the ozone columns in 0-25 km and 0-60 km layers (except winter and early spring months), whereas the MSNSA data overestimate measurements in this period and are in good agreement with the latter in the rest of the year.

No significant trends in ozone columns are observed in simulations, while the measurements show approximately 2% / decade decrease and increase in 0-25 km and 25-60 km layers, respectively.

References

[1] P. Jöckel, H. Tost, A. Pozzer, C. Brühl, J. Buchholz, L. Ganzeveld, P. Hoor, A. Kerkweg, M. G. Lawrence, R. Sander, B. Steil, G. Stiller, M. Tanarhte, D. Taraborrelli, J. van Aardenne, and J. Lelieveld, *Atmos. Chem. Phys.*, 6, 5067-5104, doi: 10.5194/acp-6-5067-2006, 2006.

[2] Smyshlyaev S.P., Virolainen Ya.A., Motsakov M.A., Timofeyev Yu.M., Poberovsky A.V., Polyakov A.V. *Izvestiya, Atmospheric and Oceanic Physics*, 2017 (in print).

[3] Bhartia P.K., McPeters R.D., Flynn L.E., Taylor S., Kramarova N.A., Frith S., Fisher B., DeLand M., *Atmos. Meas. Tech.*, 6, 2533–2548, 2013

The Russian Scientific Foundation (project 14-17-00096) supports this research.