Diurnal Variation in Middle Atmospheric Ozone by Ground Based Microwave Radiometry at Ny-Ålesund

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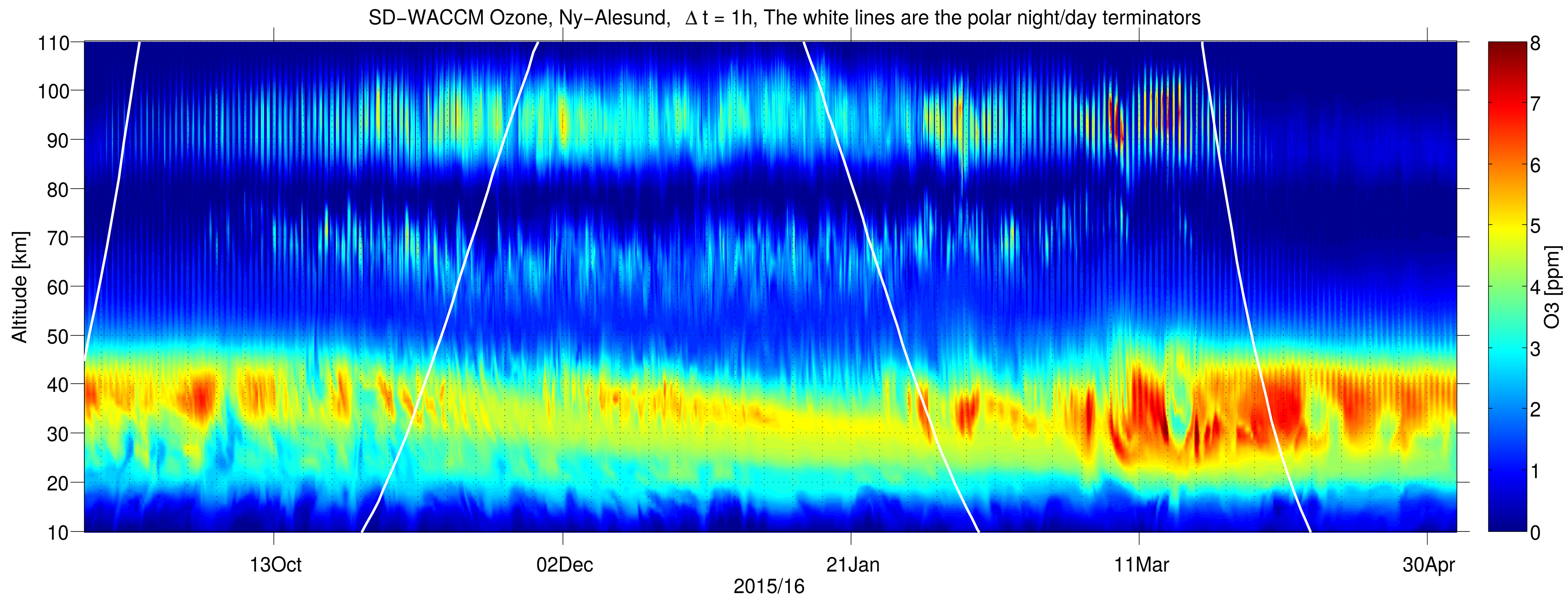
SD-WACCM Ozone Time Series



SD-WACCM is the specified dynamics version of WACCM which is the Whole Atmosphere capability of CAM the atmospheric component of the CESM model.

Specified Dynamics means that the model is nudged by GEOS5 meteorological data up to an altitude of 50 km by 10% at every time step.

The altitude range of the model is 0 - 140 km, the internal time resolution is 30 minutes, the horizontal resolution is 1.9°l at x 2.5° long and the range in vertical resolution is 0.5 - 4 km.

The time resolution of the model output is set to 1 hour which allows the study of diurnal variations in ozone which are very well captured by the model.

The figure on the left shows the model output of an SD-WACCM simulation for Ny-Ålesund, Svalbard 79°N/12°E. It shows the ozone layer at 35 km, the secondary ozone maximum at 95 km and the tertiary ozone maximum at 70 km.

The white lines in the figure indicate the polar night and polar day terminator respectively.

GROMOS-C

GROMOS-C (Ground based Ozone MOnitoring System for Campaigns) is a ground based microwave radiometer built at the University of Bern.

It measures the 110 GHz ozone emision line in the four cardinal directions (N-E-S-W).

The altitude range of the instrument is 18 - 73 km with a vertical resolution of 10 - 20 km.

Is has a very high time resolution of up to 1 hour which gives the possibility to study diurnal variations in ozone.

Since September 2015 it is located at the AWIPEV research base at Ny-Ålesund, Svalbard 79°N/12°E in the Arctic.

Tertiary Ozone Maximum

Theory

The tertiary ozone maximum is a phenomenon occuring during arctic winter at an altitude of approximately 72 km. It is explained by a relative decrease in the concentration of the OH radical which is a catalytic destructor of odd oxygen.

The main source of OH in the mesosphere is the photodissociation of water vapour by radiation with $\lambda < 185$ nm. In the region close to the polar night terminator the grazing incidences of solar radiation and the subsequent high optical depth of the atmosphere cause a sharp attenuation of solar radiation with $\lambda < 185$ nm and therefore a significant decrease in OH production.
This decrease in OH is not compensated with a reduction of ozone production (eq. 1) via phododissociation of O_2 which needs radiation with $184 < \lambda < 242$ nm (Schuman Runge bands and Hertzberg continuum). This results in a local night time maximum in ozone volume mixing ratio. (According Marsh et al., 2001)

Retrieval and Convolution

For the retrieval of the ozone profiles from the spectra measured by GROMOS-C an apriori profile is needed. This profile was chosen to be constant above an altitude of 60 km.

To be able to compare the high resolution profiles of the model with the lower resolution measurements the SD-WACCM profiles are convolved with the averaging kernels of GROMOS-C. The formula for the convolution is

$$x_{conv} = x_{apriori} + AVK(x_{model} - x_{apriori})$$

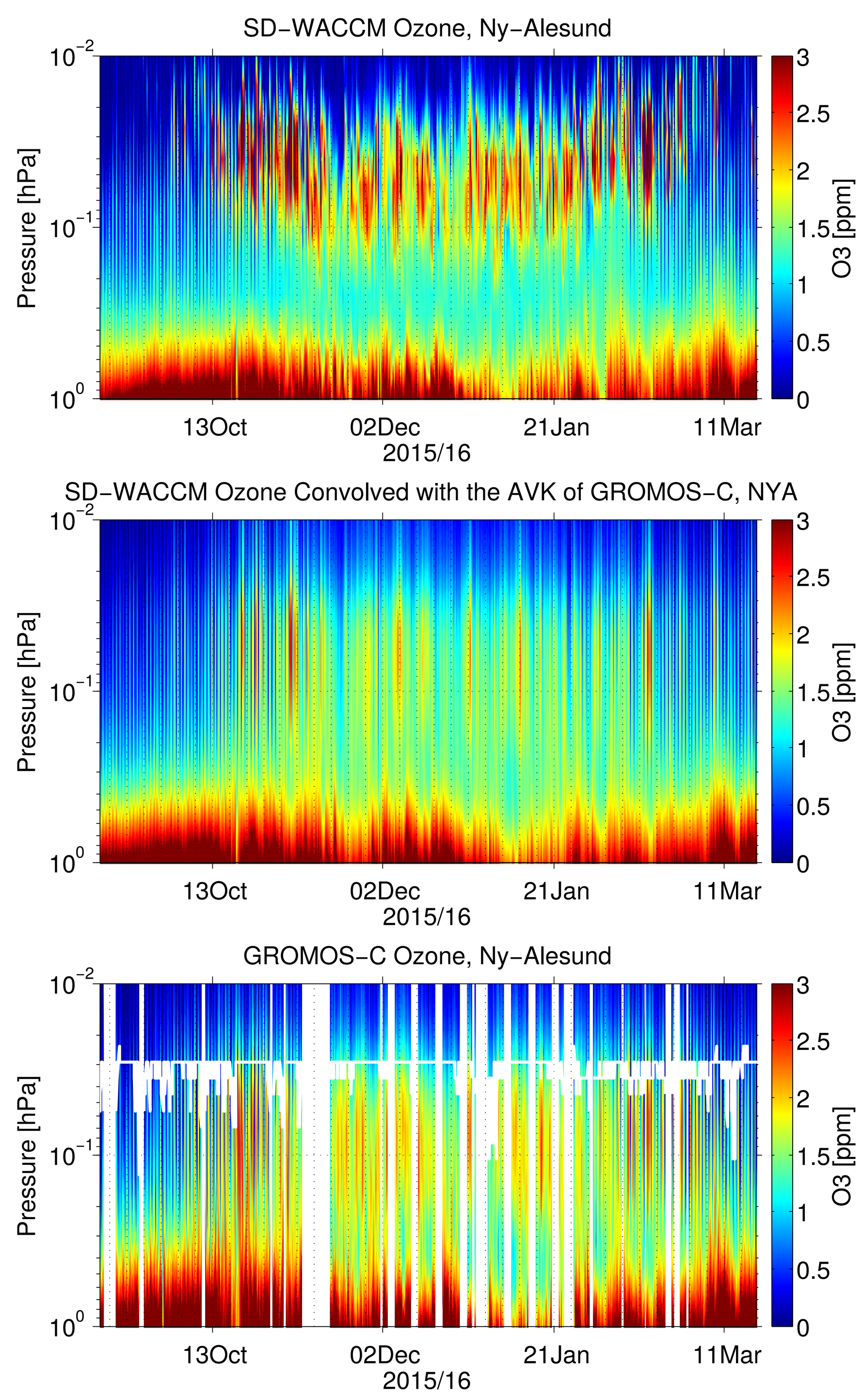
where $x_{apriori}$ is the apriori profile, x_{model} is the profile modeled with SD-WACCM and *AVK* is the averaging kernel.

Discussion

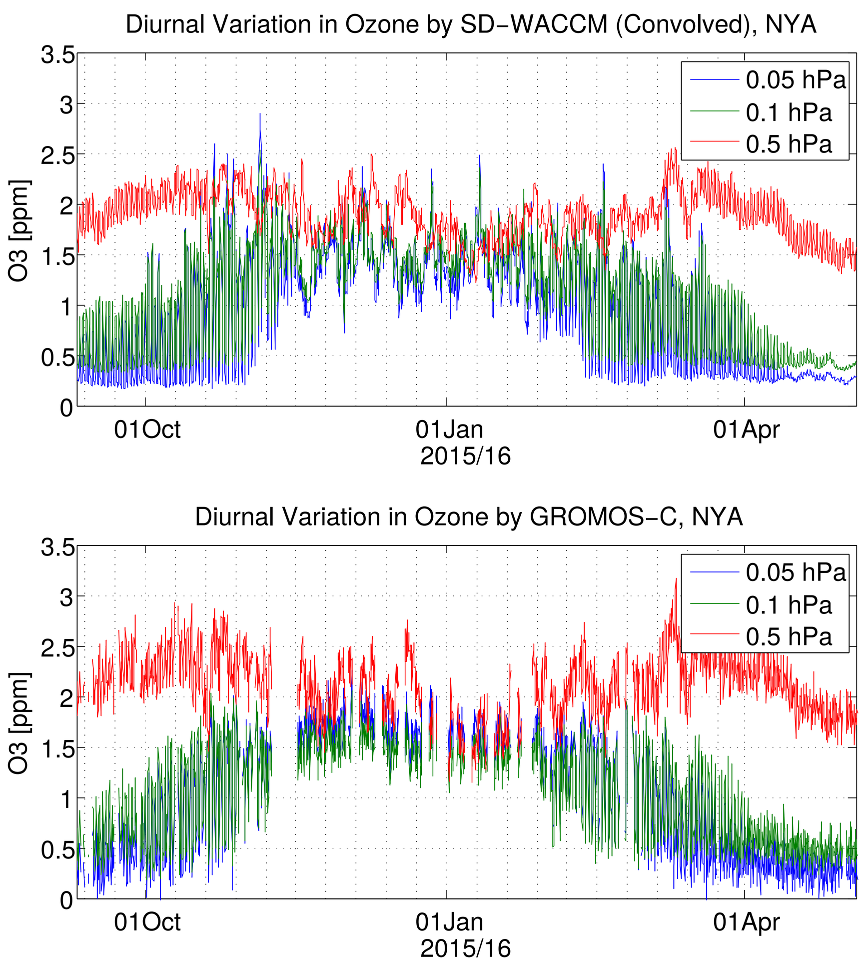
The tertiary ozone maximum is clearly visible in the measurements of GROMOS-C.

The white line in the figure represents the measurement response of 0.8. The tertiary ozone maximum measured by GROMOS-C lies in the region with a measurement response higher than 0.8.

The convolution of the model data has lowered the tertiary ozone maximum by about 3 km and agrees with the position of the tertiary maximum of the measurement.



Diurnal Cycle of Ozone



The Diurnal Cycle of Ozone in the Mesosphere

The amount of ozone in the mesosphere is controlled by two reactions. Ozone is produced from three body recombination of atomic oxygen

$$O + O_2 + M \longrightarrow O_3 + M \qquad (1)$$

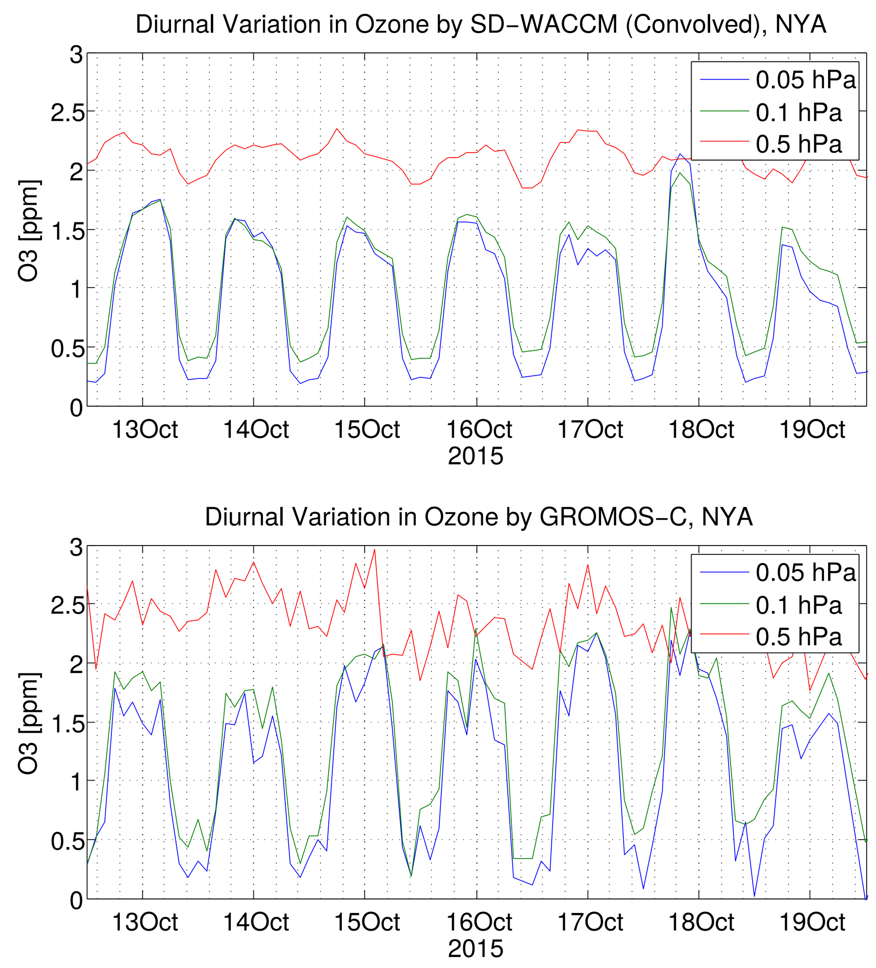
and destroyed by photolysis

$$O_3 + h\nu \longrightarrow O_2 + O \qquad (2)$$

During day odd oxygen is present as O and O_3 while during night the production of ozone shuts off and the atomic oxigen recombines. This enhances the amount of ozone and leads to a night time maximum in ozone. While rising in altitude (1) gets less efficient, since it depends on atmospheric density, and the depletion of ozone during day increases. Therefore the amplitude of the diurnal cycle of ozone grows with increasing altitude.

Discussion

The left panel shows the diurnal cycle of ozone for different altitudes above Ny-Ålesund from SD-WACCM simulations and GROMOS-C measurements. The seasonality of the diurnal cycle is very well captured. The amplitude of the variation is low during polar day but gets high in autumn and spring and is blurred during polar night.
The right panel contains a zoom of mid october and reveals that the amplitude of the variation is of about 1.5 ppm at 0.05 and 0.1 hPa and significantly lower at 0.5 hPa.



Conclusion and Outlook

GROMOS-C is very well capable of observing diurnal variations in ozone with a very high time resolution.

The campaign at Svalbard is ongoing until 2018 which allows us to study the diurnal cycle in more detail.

Acknowledgement

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