Ozone minihole observation over the Balkan Peninsula in March 2005

R. Werner (1), D. Valev (1), A. Atanasov (1), I.Kostadinov (1,2), B. Petkov (1,2), G. Giovanelli (2), K. Stebel (3), A. Petritoli (2), E. Palazzi (2), M.Gausa (4)

(1) Solar-Terrestrial Influences Laboratory, Bulgarian Academy of Sciences, Bulgaria
(2) Institute of Atmospheric Sciences and Climate, Italian National Research Council, Italy
(3) Norwegian Institute of Air Research, Norway,
(4) Andoya Rocketrange, ALOMAR, Norway
rwerner@stil-sz.org

The Arctic winter 2004/2005

The development of the arctic vortex started in the early October and until November it was fully completed. The arctic winter from December to January is usually cold and until late January no warming signs were established. The stratospheric temperatures were near the record lowest ones and in December to February conditions existed for formation of polar stratospheric clouds, which allowed enhanced ozone destruction.
When the vortex was fully developed, the vorticity had high values and the vortex extended over a large area. The vortex displacements were caused by warming, and the vortex could be observed over Central Europe and in same cases - over South Europe, too.
In the beginning of February, due to planetary wave activity, the vortex was elongated and its south edge was located over South Europe and low stratospheric temperatures were observed over the Stara Zagora region. At the end of February and from the beginning to the end of March polar vortex filaments passed over the Balkan Peninsula, producing peaks in the polar vorticity. After the middle of February the vortex was significantly warmed and on 25 February was split by wave activities. Then the vortex recovered, yet this winter it never achieved very low temperatures. In the first ten days of March pres pyrwite deset dni the polar vortex was again disturbed and elongated, almost split in two fragments. Between 17 and 22 March the disturbance was so strong that the vortex was split in three fragments. One of them was located over North Italy and the Balkans. In this connection, low stratospheric temperatures were registered and high polar vorticity values were observed over Stara Zagora. After that the polar vortex was destroyed and the polar summer conditions resumed.

Ozone miniholes

It is not exists a strictness definition for term ozone minihole. In general by this term is named an event of fast ozone depletion to very low values over an area of up to a several thousand km^2. The life time of the event is only a couple of days. Mostly values between 220 and 230 DU as threshold are used. Some authors are use definitions based on the relative ozone depletion in connection with statistic measures as zonal variability and zonal means and the standard deviation calculated for certain time periods for example. The ozone miniholes are generated mainly by atmospheric dynamic processes such as advection of ozone-poor subtropical air masses or from polar- regions or, they are produced by undulation of the tropopause height. Some times miniholes are also observed by presence of PCS's. During the summer at high latitudes the chemical destruction of ozone and advection processes lead also to miniholes, however in general the occurrency of strong miniholes is more frequently at winter and at the northern hemisphere they are located over the northern Pacific and northwestern Atlantic European Region. It was observed, that low ozone European events in the decade of the nineties in the winter was more frequent than in the fifties/sixties. The reason for this increase is the decreasing of the mean ozone level and changes in the local atmospheric dynamic, which is consistent to the found effect of the North Atlantic Oscillation pattern (NAO) on the minihole frequency.

The March ozone minihole

By ground-based measurements, carried out with the GASCOD instrument on 21th of March over Stara Zagora, low total ozone amounts below 220 DU were observed. Besides, low ozone column values of 270 DU were found for this time and this location by interpolation of the EP TOMS gridded data (see Fig. 1). The record lowest ozone value of 237.1 DU was measured since 1978 over Sofia by all TOMS instruments (see Fig. 2). This low value is in good agreement with the morning GASCOD measurements at Stara Zagora, which are provided in western direction towards Sofia.

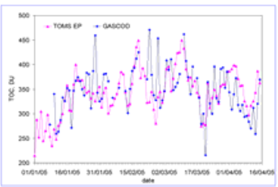

Fig. 1. Time series of the GASCOD ground-based total ozone measurements at Stara Zagora from January until April 2006.

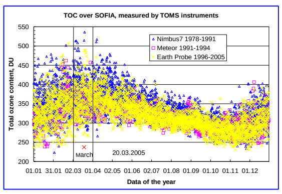

Fig. 2. Complete TOMS instruments and Meteor measurements of the total ozone column from 1978 until 2005 for the Sofia overpass location.

The SCIA assimilated total ozone distribution (at Fig. 3) shows the development of the area over Middle Europe with fast TOC decrease, which begins about 14 March over Iceland (not shown here). On the next days the area with decreasing TOC increases and moves southwards and eastwards.
The ENVISAT/SCIAMACHY (SCIA) assimilated total ozone maps

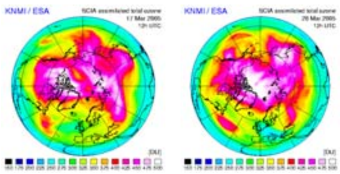

Fig. 3. SCIA Assimilated total ozone columns for 17 March (left) and 20 March (right). The maps demonstrate the development of an ozone minihole over Central Europe. The eastern flank of the minihole on 20 March covers the West Balkan Peninsula.

suggest that poor ozone tropical air mass was transported westwards from the Canaries to Iceland. Actually, on 17th March an extended high-pressure system was located over France and the Mediterranean. On the next days the anticyclone was developed and a strong ridge with deep cyclones at its flanks was built up (Fig. 4).

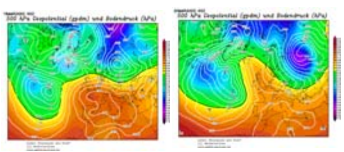

Fig. 4. The Geopotential maps at the 500 hPa level for 18 March (left) and 20 March (right) show the development of the rosby wave ridge over North-Western Europe.

This strong Rossby wave activity reaching up to the lower stratosphere disturbed the polar vortex. By warming episodes over a geographical area, covering the Barent Sea and the Polar Sea north from Central Siberia (see geopotential map at Fig. xx), the vortex was split and one vortex fragment was displaced extremely southwards. The wave ridge was located below the European vortex fragment.
The tropical air was advected from the south to the north on 17 March by strong wind shear from the western ridge flank. The pressure map at the level of 2 potential vorticity units (PVU) on 17 March showed the ridge with low pressure air mass (blue color) from the Atlantic to the south of Great Britain, which coincided with the high potential temperature ridge with low pressure air mass (blue color) from the Atlantic to the south of

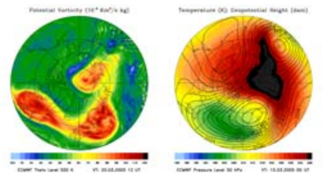

Fig. 5. The polar vortex map for the Northern hemisphere on 20 March (right) shows clearly the vortex split, which is caused by warming over the Barent Sea and the Polar Sea, which is seen on the temperature map for the 50 hPa level (left).

Great Britain, which coincided with the high potential temperature (yellow color, see Fig. 6).

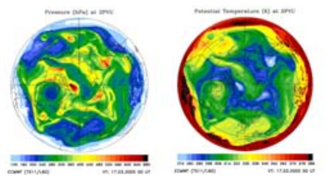

Fig.6. The pressure (left) and the potential temperature (right) at the two potential vorticity unit levels. Low pressure air mass (200hPa ÷ 220hPa) with high temperatures (330K ÷ 340K) is transported from the Atlantic to the North-Western Europe.

This air mass was warm and dry and was characterized by its low ozone content. The tropopause in the tropic is typically higher than the tropopause at the extra tropic. The dynamical horizontal motion is coupled with vertical advection in the case of the wind shear between a cyclone and an anticyclone. During the Alps overpass, the air mass was additionally uplifted. Thus, the minimum of the ozone minihole was observed over Northern Italy.
The HYSPLIT model served to calculate backward trajectories with an endpoint at the geographic location over south of Great Britain and Rila mountains. At upper tropospheric altitudes, the air mass originated from the Atlantic, moving to the north north-east up to the European North Sea and after that, the air mass moved to the south-east. At higher altitudes, the air mass transport was directed

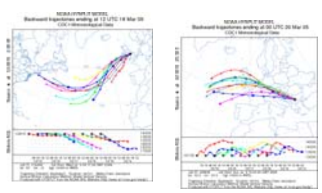

Fig.7. Four-days' backward trajectories, calculated with the Hysplit model, for the ending on 19 March over Great Britain and on 20 March over West Bulgaria

strongly from the west to the east (not shown here). The calculated trajectories were in a good agreement with the expected air mass transport from the geopotential maps at different isobaric or isentropic levels. In the period from 10 to 19 March, the tropopause height over the Sofia region was uplifted more than 3 km, at levels, typical for the

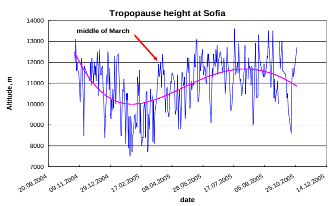

Fig. 8. Development of the tropopause height over Sofia, calculated by help of the WMO definition from temperature profiles. The tropopause uplifting during the middle of March 2005 is marked by a red arrow.

summer time. It is well known that by the uplifting process of air mass and with the presumption that the ozone mixing ratio is not changing, the ozone column amount should decrease.
The above-described development of the ozone minihole in March allows to conclude that the formation of the minihole in March is basically predetermined by dynamic processes.
The TOC decrease is closely connected with the increase of the UV radiation obtained at the earth surface.

UV radiation over the Rila mountains

The Rila is the highest mountain in Bulgaria and Balkan peninsula. Most of high peaks are about 2500 - 2700 m a.s.l. Several peaks are higher than 2800 - 2900 m. The Mountains has alpine character and the highest peak is the Mousala 292 m a.s.l. Only 20 km to north from this peak and 70 km away south from Sofia is situated the biggest Bulgarian resort Borovez.

Fig. 9. A view of the winter sports center Borovez

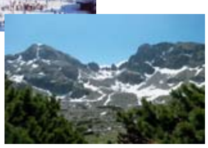

Fig. 10. The Kupena peak (2731 m a.s.l.) and the Lovnica peak (2695m a.s.l.) - parts of the Malyoviza ridge.

It offers a perfect opportunity for amateur and professional winter sport from October/November until the late April. One of the most popular excursions from Borovez is the Maljovica peak (2730 m a.s.l.)

with its ridge. The ozone minihole at the 20 March cover the south westerly part from Bulgaria. Over south Bulgaria is located a strong cloud band, connected with the could front cross this region from 19 to 20 of March. However, the Modis Satellite Aqua from 20 of March 11:23 UT shows, that the north easterly Rila mountains are

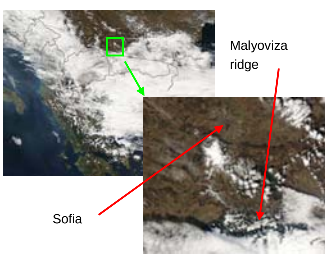

Fig. 11. Maps from the Aqua Modis Satellite for 20 March 11:23 UT. The zoomed part shows that Sofia, the Malyoviza peak and the Malyoviza ridge (eastwards from the Malyoviza peak) are widely cloudless.

mainly free from clouds. In this area the Ultraviolet radiation could be achieve the ground. The UV radiation and the UV-index were calculated by help of the Tropospheric Ultraviolet and Visible (TUV) Radiation Model for the 20 of March 2005 and for the RILA location. The results (at the Fig. xx) shown that the Ultraviolet-index for this day at middle geographic latitudes was between very high (8 ÷ 10) and extremely high (values over 10), assumed an ozone column amount of 260 DU an 237DU according to the observed satellite data (OMI and EP) and the GASCOD measurement.

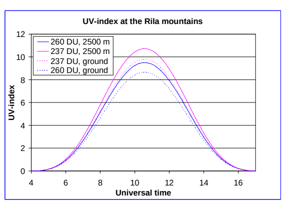

Fig. 12 The UV-index, calculated by the TUV model for 20 March for the Rila region

Conclusions

An ozone minihole event was found analyzing satellite, ground based and additional synoptic data. The minihole was situated over Central Europe. On the 20th of March it covered the western Balkan peninsula. The synoptic weather pattern shows, that the minihole was originated from ozone-poor air masses transport from the tropic to higher latitudes in the UTLS region, accompanied with uplifting of the tropopause. The low ozone content at middle latitudes in late spring, when the sun elevation is high, can be caused by very high UV radiation, reaching lower altitudes, over cloudless regions, whereupon the ultraviolet indices remain in the range from 8 to 11 which means a change of exposure from "very high" to "extremely high". When this occurs over populated areas as Sofia or over mountain tourist centers as was described here, then the population is exposed to higher UV radiation increasing the risk of skin damages.
It is necessary to study whether the occurrence of miniholes and the area covered by such holes at middle latitudes during late spring may increase in the future and eventually to draw a corresponding UV warning system.

Acknowledgement

R. Werner was supported by the European Union's 6th framework program within the ALOAMR eARI (23 RoWe) project.

36th COSPAR Scientific Assembly Beijing, China, 16 – 23 July 2006