OPERATIONAL USE OF OZONE MAPS RETRIEVED FROM TOVS DATA

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ABSTRACT

The correlations between observations and isentropic potential vorticity, 100 hPa wind fields, jet-streams and other meteorological features total ozone fields as derived from TOVS to be used operationally are underlined. A deep ozone minimum occurred on 14-15 January 1992 over Northern Europe is presented. Extraction of vertical profiles to identify stratospheric air masses intrusions is analized.

1. INTRODUCTION

Total ozone retrievals from TOVS data, received in real time at the National Meteorological Centre of the Italian Meteorological Service, are currently obtained by means of the ITPP-4 software package (Smith et al., 1985) running on a VAX 3800 computer, being part of the system for reception and processing of satellite data (ANDROMEDA system, see Pagano et al., 1991).

In particular it has been shown that the satellite total ozone retrievals, from TOVS/HIRS-2 9.6 μm channel observations are in good agreement with ground-based determinations and that satellite O₃ observations can be used to monitor the quality performance of the ground based station network (Travaglioni and Pagano, 1991).

Furthermore an operational use of satellite ozone observation is envisaged to be used as input in numerical weather prediction models (Cariolle and Muller, 1989) and for nowcasting purposes (Shapiro et al., 1982).

In fact for nowcasting applications it has been shown by Shapiro et al. (1982), the possibility of using TOMS-derived ozone maps for identifying the position of jet-streams, characterized by steep gradients in total O₃ concentration. Moreover from the analysis of the evolution of ozone fields is possible to extract information about lower stratosphere winds (100 hPa) and to follow the intrusions on different air masses, which are characterized by different ozone content. Finally the strong correlation detected between the total ozone content and the Ertel’s Isentropic Potential Vorticity (IPV) can be used as a powerful tool to get further information on the dynamical state of the lower stratosphere (Hoskins and Berriesford, 1988, Cariolle and Muller, 1989).
2. METEOROLOGICAL FEATURES DETECTABLE THROUGH OZONE FIELDS

To assess the usefulness of $O_3$ fields in support of operational activity, a few examples of ozone maps in different meteorological situations, showing interesting correlations between ozone fields and meteorological features, are here reported.

2.1. Case 1: development of a depression over Mediterranean

The reconstruction of the $O_3$ field (NOAA-11, 12:51 UTC) is presented, together with the corresponding analysis at 500 hPa at 12:00 UTC (figg. 1a,b). The deep trough over Central-Eastern Europe drives a cyclonic circulation over southernmost part of Italy, while a ridge is moving towards the Mediterranean. The isolated minimum over Sicily, associated also with storms and showers, can be very precisely correlated with the analysis of the ozone field. Very impressive is the correspondence between the 320 DU ozone contour and the contour line 5640 of the geopotential field at 500 hPa, together with the location of maxima winds in correspondence to the steepest gradients in the ozone map.

2.2. Case 2: polar cold air intrusions

Total ozone content is strongly correlated with air mass characteristics and horizontal maps can be used to trace the evolution of upper synoptic features such as in the situation that occurred between 2 and 5 December 1991. In figg. 2a,b loose gradients and ozone values lower ($\approx 280$ DU) than the season are detected in connection to the rising of the Azores anticyclone (tropical air) up to
the North-Central Europe on December 2nd.

Three days later the development of a trough over Eastern Europe favour the intrusions of polar cold air down to Mediterranean Sea. The corresponding ozone field reflects such a situation, with a strong increase in $O_3$ values ($\approx$400 DU) and relative maxima linked to instability areas (figg. 3a,b).

2.3. Case 3: Jet stream detections

The reconstruction of the ozone field (NOAA 10, 7:24 UTC) and the corresponding analysis at 500 hPa, 12:00 UTC, are presented in figg.
4a,b. A polar air mass outbreak, produced by a deep trough over the westernmost part of Europe is correlated with high values of ozone, showing the steepest gradients between the British Islands and Norway, associated to South-westerly winds before the trough axis.

The correspondence between ozone gradients and jet-stream position is also evident in the previous case (figg. 2a,b), where the steepest $O_3$ gradients are associated to the polar jet over Central Europe.

3. USE OF VERTICAL PROFILES

Although the 9.6 $\mu$m channel on board NOAA satellites is designed primarily for inferring information on total ozone content in the atmosphere, the method used in the ITPP-4 for the total ozone determination allows the reconstruction of the vertical profile. This opens the possibility of monitoring the evolution of the ozone layer enlightening the intrusion of stratosphere air into the troposphere as a consequence of the tropopause folding occurring in correspondence of jet-stream locations. In fact the vertical sections of the ozone concentration are strongly correlated to those of potential vorticity, as it is shown in figg. 5a,b (Shapiro, 1978).

In figg. 6a,b typical ozone profiles in standard conditions and a modified vertical profiles subsequent to an ozone intrusion into the upper troposphere are shown.

4. A DEEP OZONE MINIMUM DETECTION

From the analysis of ozone field (NOAA-12) a deep ozone minimum was detected over North-Western Europe on 14 and 15 January 1992.
The meteorological analysis showed that from January 9th on, the upper level analysis presents a northbound rising of the Azores anticyclone from medium Atlantic, with an anticyclonic cell remaining steadily isolated from the retiring ridge over the British Islands until 14 and 15 January. The upper air mass, being humid and rather warm, as a residual of the Atlantic anticyclone, maintained very high geopotential values over Scotland. Following the development of a blocking situation, deep depressions on either side of the
ridge produced high pressure gradients, mainly on its eastern side, and associated jet-stream with meridional component (fig. 7a). The corresponding $O_3$ field, while presenting high values associated to a strong gradient in correspondence of the jet position, showed a very deep minimum over Northern Britain (185 DU), quite unusual in that area, even in presence of tropical air (fig. 7b).

The retrieved profile at $63^\circ$N, 2.5$^\circ$W (fig. 8) showed the main peak at 30 hPa halved in respect to that of a "standard" profile.

In the framework of the Global Ozone Observing System, synoptic maps of daily mean total ozone, by means of ground-based stations, are produced by the University of Thessaloniki, Greece. Although those maps are produced with the aim of monitoring the global basic $O_3$ field, thus
filtering out local oscillations, it is possible to compare the main features in the ozone field as observed by satellite and the station network. On 14 January 1992 about 10 stations were used to plot the map (fig. 9), showing the presence of a deep minimum over North Sea, with values lower than 240 DU. The lack of a station in Northern Scotland prevented from the possibility of revealing a deeper minimum in that region. On January 15 more stations contributed, confirming the presence of a minimum over North Sea, with a lowest value of 225 DU recorded near Oslo, still in agreement with the satellite retrievals (figs. 10a,b).

Moreover, in both configurations on 2 December 1991 and 14 January 1992, it can be noted a large anticyclonic area in the North-Western part of Europe. Related ozone retrieved minima are significantly different. In January detected data present values decreasing, from 10% over France till 30% over Scotland, with respect to the previous month ones. The rising of the tropical air mass, associated with a high pressure cell, occurred over a period 2 or 3 times longer than in

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Fig. 9 UMO/GO.05 daily mean total ozone map for 1.14.1992 (Courtesy Dr. Zerefos, Univ. of Thessaloniki and Prof. Palmieri, Univ. of Rome)

Fig. 10a UMO/GO.05 daily mean total ozone map for 1.15.1992 (Courtesy Dr. Zerefos, Univ. of Thessaloniki and Prof. Palmieri, Univ. of Rome)
December 1991, and the evolution of synoptic patterns showed geopotential heights differences of about 60 msp.

Values recorded at the Italian Meteorological Service showed an increase of $\beta_{500}$ and $\beta_{380}$ atmospheric turbidity values since summer 1991, probably in connection with the Pinatubo eruption in June 1991 (fig. 11). The presence of dust in the atmosphere might have enhanced photochemical and radiative processes (heterogeneous chemistry) leading to ozone depletion (Hoffmann and Solomon, 1989). However, the available data don’t allow the understanding of the origin (dynamical, photochemical, climatological, anthropical) of these differences.

5. OPERATIONAL USE OF OZONE MAPS AND PROFILES

The meteorological analyses have shown the consistency between satellite retrieved $O_3$ and contour maps, mainly above 500 hPa, and particularly the correspondence between strong $O_3$ gradients and the position of the jet-streams.

From a cross-section analysis of geopotential height ($H$) and potential temperature ($\Theta$) along the line AA' of fig. 7b on 14 January 1992 (figg. 12 a,b), the correlation of the lowering of $H$ field and the maximum of $\Theta$ with the ozone minimum, located around 10°E, can be pointed out. This cross-section has been obtained using only satellite data and is in a good agreement with the features showed by Hoskins et al, 1985. In such a way we can infer the characteristics of the IPV field through the $O_3$ field. Indeed the
knowledge of IPV, as a conservative quantity, is particularly important for following motions at the tropopause level.

Fig. 12a Potential temperature $\theta$ (every 20 °K) for the cross-section AA' of fig. 7b.
- x-axis: latitudes x 100; y-axis: pressure levels (hPa)

Fig. 12b Geopotential heights $H$ (every 2000 mge) for the cross-section AA' of fig. 7b.
- x-axis: latitudes x 100; y-axis: pressure levels (hPa)

Similarly, from the use of vertical profiles is possible to identify the intrusions of stratospheric air, with higher values of $O_3$, into the troposphere in the upper part of the frontal zone. This is evident from figg. 6a,b, on the same day, where a remarkable increase in $O_3$ concentration around 400 hPa is detected across the jet-stream, whose location is shown in fig. 13, together with the height
of the tropopause. The same intrusion, occurring at 44°N, is more evident from the vertical section of ozone content at 10°E obtained from the vertical profiles (fig. 14). It is worth noting that the highest concentrations of tropospheric ozone are associated with a residual instability area over the Mediterranean. Furthermore, since low level disturbances due to baroclinic instability are related to

![Fig. 13 Tropopause and jet-stream analysis on 1.14.1992 at 12:00 UTC](image)

![Fig. 14 Ozone cross-section (10^16 mol cm^-2) retrieved on 1.14.1992 between 48.3°N,10°E and 37.3°N,10°E](image)

the upper level configurations, hence to the total ozone content (Cariolle and Dequé, 1986), the possibility of using asyroptic satellite O₃ maps to infer further information on the evolution of
contour gradients outside the NWP outputs has been considered.

6. CONCLUSIONS

The potentiality of using measurements of total atmospheric ozone content for operational meteorology has been shown through a comparative analysis of satellite-derived total ozone fields, with the information routinely available, such as contour maps, tropopause/maximum wind charts complemented by satellite imagery. The O₃ fields have been obtained from TOVS/HIRS-2 data, received in real time from NOAA-11 and NOAA-12 satellites, and available operationally at the NMC of the Italian Meteorological Service.

Being a good passive tracer of atmospheric motions, ozone observations can become an important tool to be used by forecasters for inferring useful information about upper troposphere, jet-stream location and identification of instability areas, through the close correlation with the IPV. Moreover the possibility of extracting vertical ozone profiles from operational satellite observations gives a mean for monitoring vertical motions at the tropopause level, mainly in occurrence of the breaking of the tropopause and the intrusion of stratospheric air downwards, associated with the transfer of potential vorticity into the upper troposphere.

The present satellite scenario, however, although offering a unique possibility for the operational use of O₃ data, is still far for fulfilling the requirements of space, time and vertical resolution needed for real nowcasting applications. Therefore, in the framework of the studies for designing the satellite scenario for the years 2000, it has been decided, within ESA and EUMETSAT, to include an infrared "ozone channel" in the 11-channel imaging radiometer SEVIRI for Meteosat 2nd Generation, gaining also from the synergy with the high spectral resolution sounder IASI, to be flown on the future polar orbiting satellites. With the introduction of the new generation instruments, the production of total O₃ maps every 15 minutes and profiles with a vertical resolution of some 4-5 km will be possible, allowing, inter alia, the extraction of wind vectors in the stratosphere from ozone patches and a continuous monitoring of the evolution of the altitude fronts.
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