ABSTRACT

Since the beginning of 2004, ozone column images are derived at Météo-France/CNRM from the MSG/SEVIRI thermal infrared radiances. Results from a research version of the algorithm developed by CNRM after the availability of MSG data are presented. After a short presentation of the principle used for the derivation of ozone columns and their uncertainty, section 2 explains the decomposition of the uncertainty in two components of different horizontal scales that is relevant for operational as well as for science applications. Section 3 presents a potential application in operational weather forecasting that could be used in Potential Vorticity analysis. Section 4 provides preliminary results of comparisons of the SEVIRI Total Ozone product with other determinations of the ozone column. The consistency with total ozone determinations derived similarly from the HIRS instrument of METOP opens the way to interesting applications.

1. INTRODUCTION

The new channel of SEVIRI at wavelengths near 9.7 microns provides an opportunity to observe the ozone column at unprecedented time and space resolutions, in near real time conditions. We present there a preliminary evaluation of the total ozone products derived at CNRM Toulouse from the raw MSG radiances. The work presented has been carried out in the frame of the Satellite Application for Ozone Monitoring that is hosted by the Finnish Meteorological Institute. In 1999, CNRM/Météo-France had the task to provide a total ozone algorithm to EUMETSAT that became the operational product, now delivered regularly by the Meteosat Product Extraction Facility of EUMETSAT at moderate time (every 3 hours) and space (50 km) resolutions. Results presented here are obtained with a “research” version of the CNRM ozone algorithm that has new enhancements with respect to the operational version (see the result of the new version on Fig. 1). In particular, the calculation of the noise level of the products has been improved and a partial ozone column between the levels 400 and 40 hPa was derived (see on Fig. 2). For investigating variations of ozone in the lower stratospheric region, the SEVIRI Partial Ozone (SPO) is a more accurate product than the total column. However, validation data for SPO are still not easy to access. Therefore the rest of this paper only deals with the SEVIRI Total Ozone (STO) product.

2. THE CNRM TOTAL OZONE ALGORITHM

The Total ozone algorithm uses the determination of the slant ozone transmission in the 9.7 microns ozone absorption band. The transmission is determined by a spectral differential method that uses the difference of the radiances observed from space in 2 window channels (10.8 and 9.7 microns, the latter is sensitive to absorption by the ozone).

Fig. 1. Ozone column from SEVIRI instrument processed at full resolution for 2004, March 12, at 00H UTC

Regressions are used to determine corrections to the foreground and background temperatures that are respectively the radiative temperatures of the ozone layer and the atmosphere and Earth just below the ozone. A final regression is used for deriving the ozone column from the slant transmission. The principles are
explained in [1] and [2]. The set of measured radiances for each pixel is used independently from the neighbour pixels. The horizontal resolution of the product is therefore the same as that of the SEVIRI instrument.

2.1 Uncertainty of the derived ozone column

Errors of the Total Ozone determination have their origin in various contributions:
(1) the instrumental noise included in the measurement of the radiance in each channel,
(2) residual errors performed by the regression equations used in the algorithm,
(3) the uncertainty of the top of cloud properties as well as on surface parameters,
(4) the errors of spectroscopic data used to perform synthetic radiance spectra.
(5) In addition, the atmospheric profile conditions play a significant role in amplifying the errors listed above. If the background and foreground temperatures are very close together, the accuracy of the determination is very low because the difference of these temperatures is used as a dividing factor in the determination of the transmission.

Taking into account the fact that error sources 1) and 3) may change from one pixel to its neighbour, and that errors 2), 4) and 5) change at larger scales when they contribute in the upper atmosphere, it is possible to separate the uncertainty of the total ozone determination into two components of different horizontal scales:

- a small scale noise (SSN) that depends on the instrumental noise level and of the observing conditions.
- a systematic large scale bias (LSB) that depends both on latitude, season, and corresponding to high stratosphere characteristics.

SSN can be determined for each MSG image and is used in the algorithm to threshold the pixels where the noise level is too high. Coloured areas of Fig.3 show that the SSN level is less than 20 D. U. everywhere except over cold surfaces mainly corresponding to high cloud tops. In most places SSN is below 10 D. U. SSN can be lowered by reducing the horizontal resolution of the image.
LSB can be estimated by comparing the total ozone columns derived from synthetic radiances with the actual ozone columns of the profiles which are used to calculate the synthetic radiances. An example of estimation of LSB is given in Fig. 4. However, for the determination of systematic errors, the direct comparison to observations of other instruments is preferred and is being prepared for long term comparisons (see paragraph 4).

2.2 Intended users of the products

The separation of uncertainties in SSN and LSB components is performed because the quality of the total ozone imagery in terms of spatial variations and their consistency with weather patterns is better than the accuracy required to monitor long term ozone changes. Nevertheless, applications in the field of ozone climatology are still possible and can be used as a redundancy in case of unavailability of ozone observations from instruments using the UV spectral domain (TOMS, GOME).

Applications that can benefit from the use of the HIRS Total Ozone and SEVIRI Total Ozone products are mainly:
- support to weather forecasts: validation of an analysis of Potential Vorticity by visual comparison with the HTO or STO product,
- ozone winds extraction: the detection of structures in the total ozone image and their detection in successive images (as those of Fig. 5, but displayed at much higher resolution); this application needs observation from a geostationary platform,
- research on dynamical and chemical processes at small scales in the atmosphere: evolution of filamentary structures.

Fig 5. Evolution of ozone column from SEVIRI instrument over north Atlantic from 2004 March, 11, 12H UTC to March 12, 12H UTC, every 3 hours (March 12, 06H UTC is missing)

3. MSG TOTAL OZONE AS A TOOL FOR SHORT RANGE WEATHER PREDICTION

At mid latitudes, maps of potential vorticity (PV) at levels close to the tropopause provide a thorough description of the upper atmospheric flow that influences cyclogenesis and deep convection, both processes which are associated with severe weather. The property of PV of being a conservative quantity allows to detect on 24 to 48 hours old PV analyses the features that are precursors of severe meteorological conditions. For prediction purposes, it is therefore crucial for a forecaster to have at his disposal observations that are able to validate the model produced PV analyses or that display the same type of structures as those he may observe on the PV maps. The useful validation refers to the detection, positioning, time evolution or intensity of the features revealed by the PV distribution (Fig. 6). Presently, this validation is performed using the water vapour channel images of Meteosat that mark the synoptic vertical velocities in the vicinity of the tropopause (see [3]). Ozone images of the lower stratosphere are expected to provide complementary information on the flow not available in water vapour images.

Fig. 6. Superimposition of 1.5 PVU field and SEVIRI ozone field. The small structures of ozone field match the PV analyses well, except in some regions as shown by the arrow at the left side of the image. These regions will be studied carefully by meteorological forecasters.

4. COMPARISON OF SEVIRI TOTAL OZONE WITH OTHER INSTRUMENTS

4.1 SEVIRI - HIRS comparison

This comparison is intended to check the consistency of products that are derived using the same principle (from
the polar orbiting HIRS instrument and from the geostationary SEVIRI) rather than to determine biases of the SEVIRI product. Total ozone determined from 8 full disk SEVIRI images (March 2004, 11 at 12 UT to March 2004, 12 at 12 UT) is compared with total ozone derived from the HIRS (NOAA-17: red dots, NOAA-16: black dots) with the same type of algorithm developed at CNRM. A dependence of the difference (SEVIRI-HIRS) with respect to the satellite zenith distance is observed. The excess of ozone obtained with the SEVIRI algorithm in the region of the sub-satellite point was also observed in a short series of images in January 2004. This artefact of the SEVIRI algorithm combines with a situation where tropical tropospheric ozone below 400 hPa contributes to the retrieved ozone enhancement. The rather large standard deviation of the difference (SEVIRI-HIRS) near 20 D.U. is attributed to the time difference (-30 to +30 minutes) of the observations and to the different horizontal resolutions and will be investigated in more detail.

Fig. 6. Differences between SEVIRI ozone columns and HIRS ozone columns derived with CNRM algorithm.

The direct comparison of HIRS and SEVIRI product on a “Meteosat” projection shows a very good agreement (see images of Fig. 7 and Fig. 8). However, the excess of ozone in the SEVIRI image for the sub-satellite region can be easily observed again. In order to use for both instruments algorithms that are as similar as possible, the foreground temperature was determined for both algorithms with help of analysed stratospheric temperature fields, which is usually not necessary for HIRS instrument because it has stratospheric temperature sounding channels. If the zenith angle dependence is confirmed by a longer time period comparison that that used in Fig. 6, we will slightly correct the zenith angle dependence of the SEVIRI Total ozone algorithm.

Fig. 7. SEVIRI ozone column for 2004, March 11th at 12 H UTC derived with CNRM algorithm.

Fig. 8. HIRS (NOAA-17) ozone column for 2004, March 11th at 12 H UTC derived with CNRM algorithm (and stratospheric temperature fields).
4.2. **SEVIRI - SCIAMACHY comparison**

The comparison of SEVIRI Total Ozone with total ozone derived by data assimilation techniques from SCIAMACHY observations (H. Eskes, KNMI) is intended to investigate the systematic bias of the SEVIRI product as a function of geographical location and of the seasons. This method allows both to compare strictly simultaneous data and to compare the partial ozone column product derived from SEVIRI. A preliminary comparison has been performed with SCIAMACHY level 2 data and is shown in Fig. 9 in relative differences versus zenith angle. The general behaviour with a zenith angle dependence of the difference appears again but the differences are larger than with HIRS products. The 10% standard deviation is more easy to relate with the time difference of the observations (less than 3 hours) and with the horizontal resolutions of the two data sets which differ by more than a factor 10. A similar plot versus latitude has been drawn, but no dependence versus latitude is observed.

![Fig. 9. Relative differences between SEVIRI ozone columns derived with CNRM algorithm and SCIAMACHY ozone columns derived with TOSOMI algorithm (KNMI)](image)

4.3. **HIRS, SCIAMACHY TOMS**

To get a first idea of the way the SEVIRI product compares with other Total ozone determinations, we plotted on Fig. 10 and 11 respectively an ozone field obtained by data assimilation at KNMI and the TOMS (version 7) gridded data for the same date of March 11, 2004 at 12 UTC. These comparisons will be performed systematically with level data as soon as the zenith angle dependence of the SEVIRI product will be solved.

![Fig. 10. Assimilated ozone field from SCIAMACHY ozone column derived with TOSOMI algorithm (KNMI) for 2004, March 11\(^{th}\), at 12 H UTC](image)

![Fig. 11. TOMS ozone column for 2004, March 11\(^{th}\), at 12 H UTC](image)
5. CONCLUSIONS

First results obtained with the processing of MSG raw radiances shows that the ozone products are of good quality (low noise, large latitude and zenith angle validity domain) and that they will allow the study of applications for operational meteorology where the sensibility to lower stratospheric ozone is required together with the basic characteristics of the MSG data: high time and horizontal resolutions, and near real time availability.

Careful determination of the systematic errors of the SEVIRI products (total and lower stratosphere ozone columns) are in the process to be systematically studied through comparison with observations from the ENVISAT mission.

6. REFERENCES

