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Contract Report to the European Space Agency

Monitoring and Assimilation of SCIAMACHY, GOMOS and MIPAS retrievals at ECMWF

February 2009

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Annual report for ESA contract 21519/08/I-OL:
Technical support for global validation of ENVISAT data products

European Centre for Medium-Range Weather Forecasts
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Shinfield Park, Reading, Berkshire, UK

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Abstract

This report discusses the results from the operational validation and monitoring of level 2 data retrieved from the atmospheric instruments on board Envisat performed at ECMWF during 2008 in support to the ESA activities. Owing to instrumental problem, the MIPAS Level 2 dissemination was stopped in March 2004.

The NRT TOSOMI TCO produced at KNMI and distributed via the ESA funded PROMOTE consortium was the only SCIAMACHY product continuously disseminated during 2008. These data showed stable quality during 2008, with global mean differences from their model equivalent of about 2-3DU.

The dissemination of GOMOS Level 2 profiles continued in 2008. The temperature profiles showed a good level of agreement with the ECMWF temperature first guess and analyses, with departures within 1% (2K) in the stratosphere, and about 3-4% in the mesosphere. The NRT GOMOS ozone profiles showed a level of agreement with their model within -10 and +30% in most of the stratosphere (for p<40hPa), but larger in the lower stratosphere and in the mesosphere. The quality of the GOMOS water vapour profiles was generally poor at all levels, and latitudinal bands, with stratospheric values typically from one to four orders of magnitude larger values than their model equivalent.

In addition to the operational monitoring of the NRT products, a set of GOMOS data produced using only the brightest nine stars in the infra-red spectral range at dark limb were also provided for the period September to December 2007. This selection criterion guarantees the highest quality for the data. The results of the monitoring showed that the number of observations is strongly reduced (only about 15% of the data fulfilled the selection criterion) but their quality and level of agreement with the ECMWF model fields were much improved. This suggests that the data filter implemented in the BUFR converter in May 2007 is not able to filter out all poor quality data as one would have expected.

1 Introduction

The present report summarises the results from the global validation and monitoring of ENVISAT atmospheric data products performed at ECMWF under the ESA funded project 17585-CCN-1. These products, usually referred to as the Meteo products, are retrieved at ESA and available to ECMWF on their ftp servers in near-real time (NRT) in BUFR format. As far as the ENVISAT atmospheric instruments are concerned, the products routinely monitored include temperature, ozone and water vapour profiles from MIPAS (MIP_NLE_2P) and from GOMOS (GOM_RR__2P), as well as total column ozone retrievals from SCIAMACHY nadir measurements (SCI_RV__2P). The current project (contract 21519/08/I-OL, "Technical support for global validation of Envisat data products") runs for a period of three years from January 2008 to December 2010, and continues the work carried out under ESA contracts 14458/00/NL/SF (Dethof, 2003), 17585/03/I-OL (Dethof, 2004; da Costa Bechtold and Dethof, 2005), and 17585-CCN-1 (Dragani, 2006, 2008). The present report discusses the interim results from the monitoring and assimilation of the ENVISAT L2 atmospheric data products during the period January to December 2008.

The ECMWF deterministic model is a global spectral model. It benefits from a current horizontal resolution truncation of T799, which corresponds to about 25 km grid spacing, and 91 vertical levels with the model top at 0.01 hPa (corresponding to an altitude of about 80 km). The model uses a four-dimensional variational (4D-Var) scheme (Rabier et al., 2000) to assimilate observations at 6- and 12-hourly time windows. The ECMWF assimilation system has two main 6-hour 4D-Var (early-delivery) analysis and forecast cycles for 00 and 12 UTC and two 12-hour 4D-Var analysis and first-guess forecast cycles. The 0000 UTC analysis of the 12-hour 4D-Var analysis uses observations in the time window 2101-0900 UTC, while the 1200 UTC analysis uses observations in the time window 0901-2100 UTC. These analyses are run with a delayed-cut-off time of 14 hours (with respect to the nominal analysis times), in order to use the maximum possible number of observations. The 6-hour 4D-Var analyses have a shorter cut-off time (4 hours) and the analysis observation windows are 2101-0300 UTC for the 00 UTC analysis and 0901-1500 UTC for the 12 UTC analysis. All the observation monitoring, ENVISAT data monitoring included, is done in the delayed-cut-off analyses (Dethof, 2004) and (Haseler, 2004).

Because ozone is fully integrated into the ECMWF forecast model and analysis system (Dethof and Hólm, 2003) as an additional three-dimensional model and analysis variable, the ECMWF model can be used to monitor ozone retrievals from the ENVISAT instruments in addition to temperature and water vapour. The forecast model includes a simple ozone parameterization, which is an updated version of the Cariolle and Déqué (1986) scheme (hereafter CD86). Compared with CD86, the ECMWF ozone parameterization includes an additional term which parameterizes the depletion of ozone in the polar regions by heterogeneous reactions. At present, ozone is included uni-variately in the ECMWF data assimilation system. This means that there are no ozone increments from the analysis of the dynamical fields, even though the assimilation of ozone observations will modify the wind field in 4D-Var through the adjoint calculations. The univariate treatment was chosen to minimize the effect of ozone on the rest of the analysis system. For the same reason, the model's ozone field is not used in the radiation scheme, where an ozone climatology (Fortuin and Langematz, 1995) is preferred instead.

As far as the ozone model bias is concerned, the ECMWF model still overestimates TCO at high latitudes especially during the spring season (ozone hole) and underestimates it in the tropics. There are also some problems with the vertical ozone structure in particular at high latitudes in the winter hemisphere (Dethof and Hólm, 2004).

During the period January to December 2008, the ECMWF operational model system was upgraded twice to model cycle CY33R1 on 3 June, and to model cycle CY33R2 on 30 September, respectively. In cycle CY33r1, an improved parameterization of the moist physics and vertical diffusion were implemented in 4D-Var. We also acknowledge the active assimilation of OMI total column ozone, and AMSR-E and TMI rainy radiances. In cycle CY33R2, new VARBC bias predictors were used for correcting infrared shortwave channels affetcted by solar effects.

As far as the ozone assimilation is concerned, NRT ozone retrievals from the SBUV/2 (Solar Backscatter Ultra Violet) instrument on the NOAA-16 satellite have been assimilated in the operational ECMWF system since April 2002, and those from NOAA-17 and NOAA-18 satellites since 6 November 2007. The SBUV/2 data are produced by NOAA and available from NESDIS[1]. They are given as 20 ozone layers and then combined at ECMWF into 6 fixed ozone layers (0.1-1 hPa, 1-2 hPa, 2-4 hPa, 4-8 hPa, 8-16 hPa and 16 hPa-surface) to reduce the observation error correlation. Owing to instrumental problems, the active assimilation of NOAA-16 SBUV/2 was switched off on 21 October 2008. Apart from the SBUV/2 ozone retrievals, NRT SCIAMACHY ozone columns produced by KNMI[2] and distributed via the ESA's funded PROMOTE-2 consortium have also been actively assimilated in the ECMWF system since 28 September 2004. The active assimilation of this product was switched off on 19 December 2008 when an instrument decontamination period started which was anticipated by KNMI to result in a bias in the ozone total column product. Starting from June 2008, NRT OMI total column ozone data were also actively assimilated. SBUV/2 and KNMI SCIAMACHY data are not used at solar zenith angles greater than 84°, and OMI data are not used at solar zenith angles greater than 80°. Variational quality control and first-guess checks are carried out for all assimilated data. Temperature retrievals are not assimilated at all in the system, although this field is strongly constrained by the assimilation of radiances. The radiance assimilation does not include the assimilation of the ozone band in the infrared.

This report presents the results from the monitoring of NRT total column ozone (TCO) retrieved from SCIA-

[1] See http://orbit-net.nesdis.noaa.gov/crad/sit/ozone/ for more information.

[2] See either http://www.temis.nl/products/o3total.html or http://www.gse-promote.org/ for further information.

MACHY measurements, as well as NRT ozone, water vapour and temperature profiles retrieved from GOMOS observations. Owing to instrumental problems, NRT MIPAS Level 2 retrievals have not been available since 27 March 2004, and so this report does not discuss the monitoring of MIPAS products. This report is structured in the following way. Section 2 gives an indication of the "operationability" of ESA and KNMI products during 2008. Section 3 summarizes the results of the monitoring and assimilation of SCIAMACHY total column ozone retrievals, section 4 shows results of the monitoring of GOMOS data. Conclusions are provided in the last section.

2 Operationability of ESA and KNMI products during 2008

This section provides an indication of the operationability of both ESA and KNMI product at ECMWF during 2008, in the same way it was produced by Dragani (2008).

To assess the operationability of these products then, we have compared the data volume received within the analysis cut-off times with the total amount of data received. As anticipated above, ECMWF has two main 6-hour 4D-Var analysis and forecast cycles for 00 and 12 UTC (referred to as early-delivery) and two 12-hour 4D-Var analysis and first-guess forecast cycles (referred to as delayed-cut-off). The passive monitoring is performed with a delayed cut-off configuration, while the data actively assimilated - depending on their timely availability - are used in both the delayed-cut-off and early delivery suites.

In the delayed-cut-off, the 00 UTC analysis makes use of all the observations available in the Report Data Base (RDB) within the assimilation window between 2101 and 0900 UTC. These data are extracted in two phases. Data between 2101 and 0300 UTC are extracted from RDB at 1345 UTC; while data between 0301 and 0900 UTC are extracted from RDB at 1400 UTC. The 12 UTC analysis makes uses of all the observations available in RDB within the assimilation window between 0901 and 2100 UTC. Data between 0901 and 1500 UTC are extracted from RDB at 0145 UTC; while data between 1501 and 2100 UTC are extracted from RDB at 0200 UTC (Haseler, 2004).

The early delivery analyses make use of only six-hour observation windows. The 00 UTC analyses are obtained by assimilating all data within the assimilation window between 2101 and 0300 UTC that are available in RDB by 0400 UTC. The 12 UTC analyses are obtained by assimilating all data within the assimilation window between 0901 and 1500 UTC that are available in RDB by 1600 UTC. All the observations that fall into a given observation window but are not available in the RDB by the early delivery cut-off times can still be used in the delayed-cut-off analyses. We also note that the information from the data that cannot be actively assimilated in the early delivery system (but arrive in time for the delayed-cut-off) still indirectly affects the (early delivery) analyses as the first guess used in the assimilation are the three-hour forecasts from the delayed-cut-off.

Figure 1 shows the data volume received by ECMWF within the analysis delayed-cut-off times given above relative to the total amount of data downloaded. Values of 100% correspond to the total amount of data received within the analysis cut-off times. In contrast, 0% values mean that either there was an instrument unavailability or the total data volume was received after the cut-off times. It should be noted that because the information on the uploading times is only available on the remote (ESA and KNMI) servers for a short period (up to one week), it is not possible to cross-compare the uploading and downloading times for long periods. Therefore, delays in the data acquisition (values that are less than 100% in plot 1) could be related either to delays in the data processing, or to server access problems.

Table 1 gives the annual mean percentage of data volume received in time for the delayed-cut-off analyses during 2008, and the corresponding values for 2006 and 2007. Annual plots for the operationability of ESA and KNMI products during 2006 and 2007 were presented in Dragani (2008).

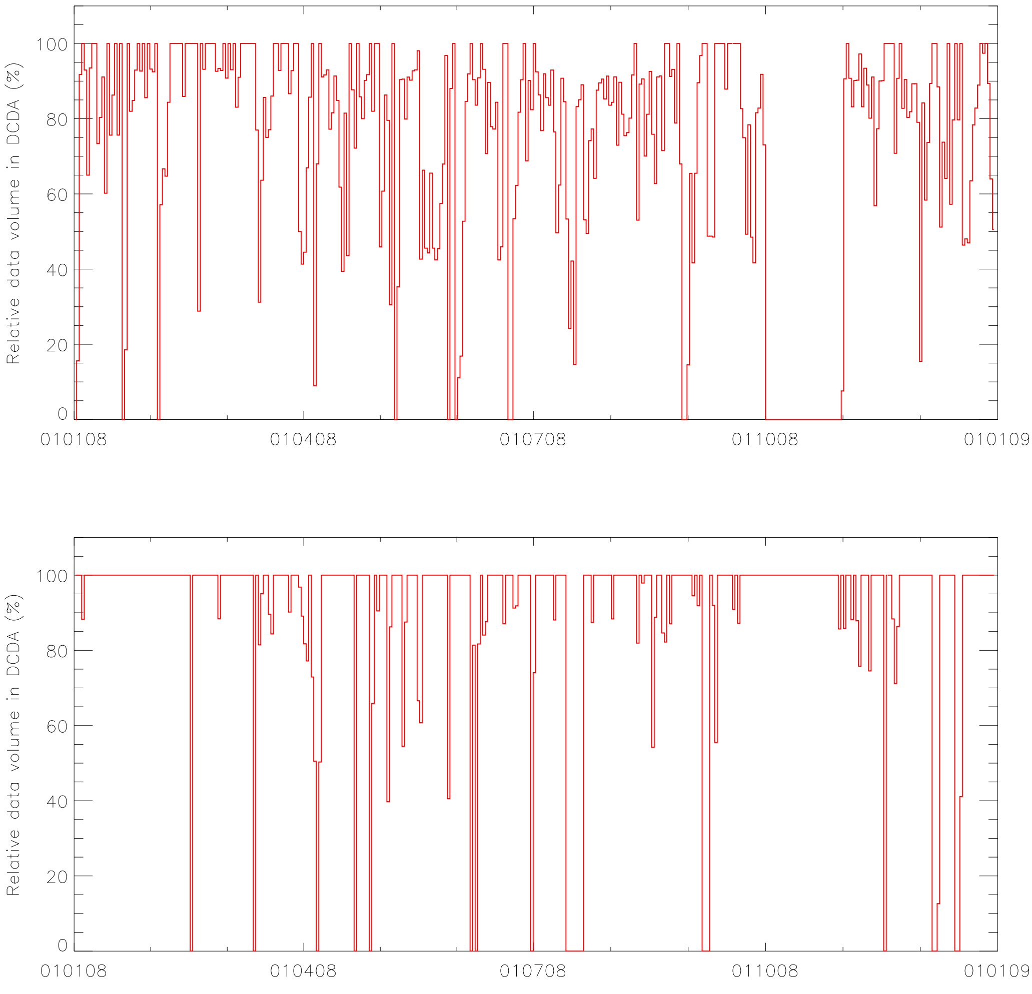


Figure 1: Time series of the daily data volume received in time for the delayed-cut-off relative to the total daily data volume received. The top panel refers to the TOSOMI total column ozone, the bottom panel refers to GOMOS data during 2008. Values are in %.

Year	GOMOS	TOSOMI
2006	96.1%	89.0%
2007	94.7%	83.1%
2008	96.4%	80.7%

Table 1: Annual mean of the data volume received by ECMWF within the delayed cut-off times relative to the total amount of data delivered. Periods of total data unavailability (such as during instrument unavailability) were not included in the annual mean.

The best timeliness was found to be that of GOMOS products, with the 2008 value being the highest in the last three years. In contrast, the timeliness of the TOSOMI product has been degrading over the last three years from about 89% in 2006 to just over 80% in 2008.

3 Monitoring and assimilation of SCIAMACHY NRT total column ozone retrievals

SCIAMACHY (Burrows et al., 1988) measures sunlight transmitted, reflected and scattered by the Earth's atmosphere or surface in the ultraviolet, visible and near infrared wavelength region (240-2380 nm) at moderate spectral resolution (0.2 nm - 1.5 nm). SCIAMACHY provides global measurements of various trace gases including ozone in the troposphere and stratosphere, as well as information about aerosols and clouds. SCIAMACHY measurements are performed in three viewing modes: nadir, limb and occultation. Depending on the type of measurement mode, global coverage is achieved within 3 to 6 days, e.g. nadir measurements yield global coverage in about 6 days.

NRT total column ozone retrievals from the nadir measurements in the UV/VIS (SCI_RV__2P) were produced operationally by ESA until 8 May 2006. These retrievals were monitored passively[3] at ECMWF in the operational suite from February 2003 until the dissemination of the Level 2 products was stopped. The latest results from the monitoring of ESA SCIAMACHY TCO for the period 1 January to 8 May 2006 were discussed by Dragani (2006).

In addition to the NRT ESA TCO, ECMWF has also been receiving NRT total column ozone data retrieved by KNMI from the nadir measurements in the UV/VIS spectral range and distributed via the ESA funded PROMOTE 2 consortium (the so-called TOSOMI product) since March 2004. This product differs from the operational ESA one as the retrieval procedure makes use of the Ozone Monitoring Instrument (OMI) Differential Optical Absorption Spectroscopy (DOAS) algorithm (Veefkind and de Haan, 2002), instead of a GOME Data Processor-like algorithm.

Owing to the unavailability of the NRT ESA SCIAMACHY TCO retrievals, it was agreed that the TOSOMI product should be regarded as the operational ESA Level 2 total column ozone retrieval from SCIAMACHY (Minutes of the ENVISAT progress meeting held at ECMWF on 6 December 2006). A summary of the monitoring and assimilation of TOSOMI total column ozone for 2008 is provided in section 3.1.

3.1 Monitoring and assimilation of NRT TOSOMI SCIAMACHY ozone column retrievals produced by KNMI

NRT total column ozone retrieved from SCIAMACHY measurements at KNMI (the TOSOMI product) was passively monitored at ECMWF from March 2004 to 27 September 2004. Based on the positive impact that these data could make on the ECMWF ozone analyses, especially in the Antarctic polar vortex region (Dethof, 2004), this product has been actively assimilated since 28 September 2004, when the model was updated to cycle CY28R3.

SCIAMACHY nadir measurements have a typical horizontal resolution of 30 km (along track) x 60 km (across track). In the ECMWF assimilation system, the KNMI SCIAMACHY retrievals are pre-thinned to a horizontal resolution of 1°x 1° before the assimilation.

[3] Data go into the system, statistics are calculated e.g. statistical analyses of the differences between the model's first-guess or analysed fields and the observations, the so-called departures, but the data is not assimilated into the ECMWF model.

The TOSOMI data dissemination continued during 2008 without major disruptions. The quality of the TOSOMI retrievals was generally stable during all 2008, and consistent with that reported in the past few years (e.g. Dragani, 2008).

Figure 2 presents the timeseries of globally averaged NRT TOSOMI ozone data, its averaged departures, standard deviations, and number of data actively assimilated with respect to the number of available observations for the periods January to June (l.h.s. panels), and July to December (r.h.s. panels), respectively. The timeseries in figure 2 show a generally stable behaviour of the data during the whole year. The first-guess and analysis departures (blue and red lines in the mid panels) were well within $\pm$5DU during 2008. A few episodes characterized by larger first-guess and analysis departures were registered during the year. These large differences are generally associated to episodes of large ozone variations in the data (only partly captured by the first guess) associated with smaller than average standard deviations. When these situations occur, the 4D-Var assimilation scheme is likely to give a large weight to the observations which can lead to large changes in the analyses. Two examples are the episodes on 14 and 20 April 2008. On 19 December 2008 following KNMI advice, the active assimilation of TOSOMI data was temporarily turned off as the SCIAMACHY instrument underwent a period of decontamination which could have resulted in a bias in the total column ozone product.

As also reported by Dragani (2008), the standard deviation of the observations (green line in the third row panels from the top) during the second half of the year shows slightly smaller mean values, as well as a smaller variability than that seen during the first six months. Also the standard deviations of the first-guess and analysis departures (blue and red lines in the third row panels from the top respectively) are slightly smaller than those during the first part of 2008, especially between January and April. In the latter case, the reduction, although apparently small (typically 1 to 2 DU smaller), still represents about 10-20% of the annualy mean value.

The generally good behaviour of the TOSOMI data can also be seen in the timeseries of the zonal mean first guess departures shown in figure 3. On average the first-guess departures (top panel in figure 3) are only a few Dobson Unit at most latitudes. However, a lower level of agreement between the model and the observations near the end of the orbits is observed especially in the winter hemisphere, and it is more pronounced in the NH than in the SH.

This reflects in the observation standard deviations (bottom panel in figure 3) which exhibit higher values than average near the end of the orbits in the winter hemisphere. Here, the observation standard deviation can reach values of 50 to 70 DU. In the tropics the observation standard deviation exhibits smaller values, typically around 10DU[4] or less.

Comparisons with independent data also show the high quality of these observations. Figure 4, in particular, shows the comparison between the time series of the zonal mean SCIAMACHY total column ozone (top panel) and of the zonal mean OMI total column ozone (bottom panel) for the whole 2008. The OMI data used in the comparisons are the NRT total column ozone distributed by NASA. On average, figure 4 shows a good level of agreement between SCIAMACHY and OMI total column ozone. Some differences can be found in the tropics, where SCIAMACHY usually exhibits lower values than OMI throughout the year, and at high latitudes where the OMI ozone values are lower than those for SCIAMACHY. It should be noted that sensors like OMI and SCIAMACHY[5] are prone to provide less precise measurements near the end of the orbits, as noted in the bottom panel of figure 3, and therefore the large differences at these latitudes should be of a less concern.

Also the monthly mean geographical distributions of the TOSOMI TCO show a good level of agreement with OMI TCO. An example is shown in figure 5 for October 2008. Top and middle panels show the geographical distribution of OMI and TOSOMI, respectively. Bottom panel shows their difference. Figure 5 confirms that the large differences between OMI and TOSOMI can be found near the end of the orbits. In the tropical region,

[4] This is consistent with what was found in the 2006 and 2007 studies (Dragani, 2006, 2008).

[5] The SCIAMACHY data used are those produced from the nadir measurements only.

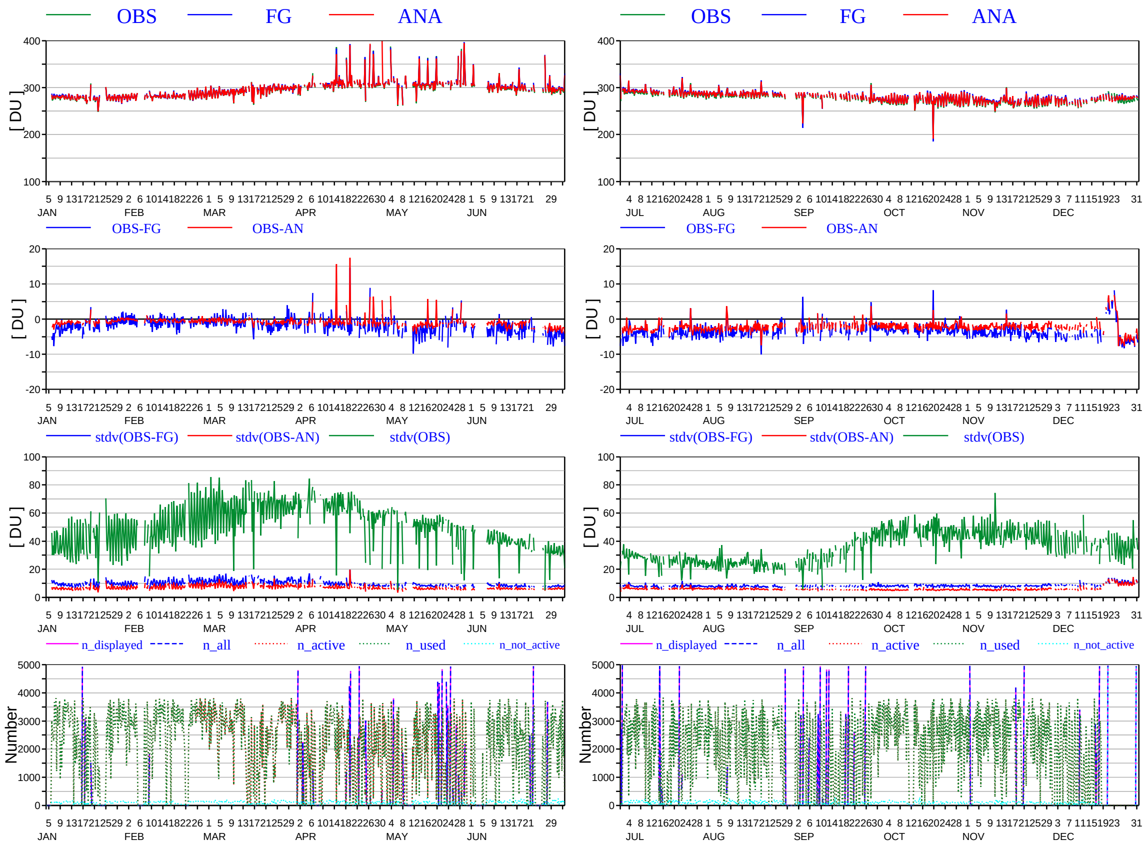


Figure 2: Timeseries of globally averaged data covering the periods 1 January to 30 June (left panel), and 1 July to 31 December 2008 (right panel). The top panels of each figure show TOSOMI SCIAMACHY NRT total ozone observations, first-guess and analysis values, the middle panels first-guess and analysis departures and the bottom panels the standard deviations of SCIAMACHY and of first-guess and analysis departures. All ozone values are in DU.

TOSOMI total column ozone values are up to 20DU lower than those of OMI.

Also comparisons between the TOSOMI data and MetOp-A GOME-2 TCO provided in NRT by EUMETSAT were performed. Figure 6 shows the geographical distribution of the monthly mean TCO difference between GOME-2 and SCIAMACHY valid for October 2008. As in the comparisons with OMI, the largest differences can be found at high latitudes near the orbit ends. Particularly noticeable are the large differences at high latitudes in the SH, as well as their patterns, also visible in the bottom panel of figure 5. This is likely to be due to the different data sampling and pixel size of the instruments considered in the comparisons. In addition, it is worthwhile to remember that the SCIAMACHY orbits are a composite of nadir and limb swaths, and that only the nadir measurements are used to retrieve the total column ozone used at ECMWF. Also uncorrected biases in the data, e.g. due to scan angle dependence, could lead to such differences. In the tropical band, the differences between TOSOMI and GOME-2 TCO are within 10 and 20 DU, as in the comparisons with OMI TCO.

3.2 Summary of the NRT SCIAMACHY monitoring and assimilation

During 2008, only the NRT SCIAMACHY ozone columns produced by KNMI (TOSOMI) were available. The quality of these data was found stable and consistent with that reported in the last few years e.g. by Dragani (2008). The monitoring statistics show a good level of agreement between the SCIAMACHY TCO and the ECMWF TCO both in the global mean and area average. In particular, the global mean first-guess and analysis

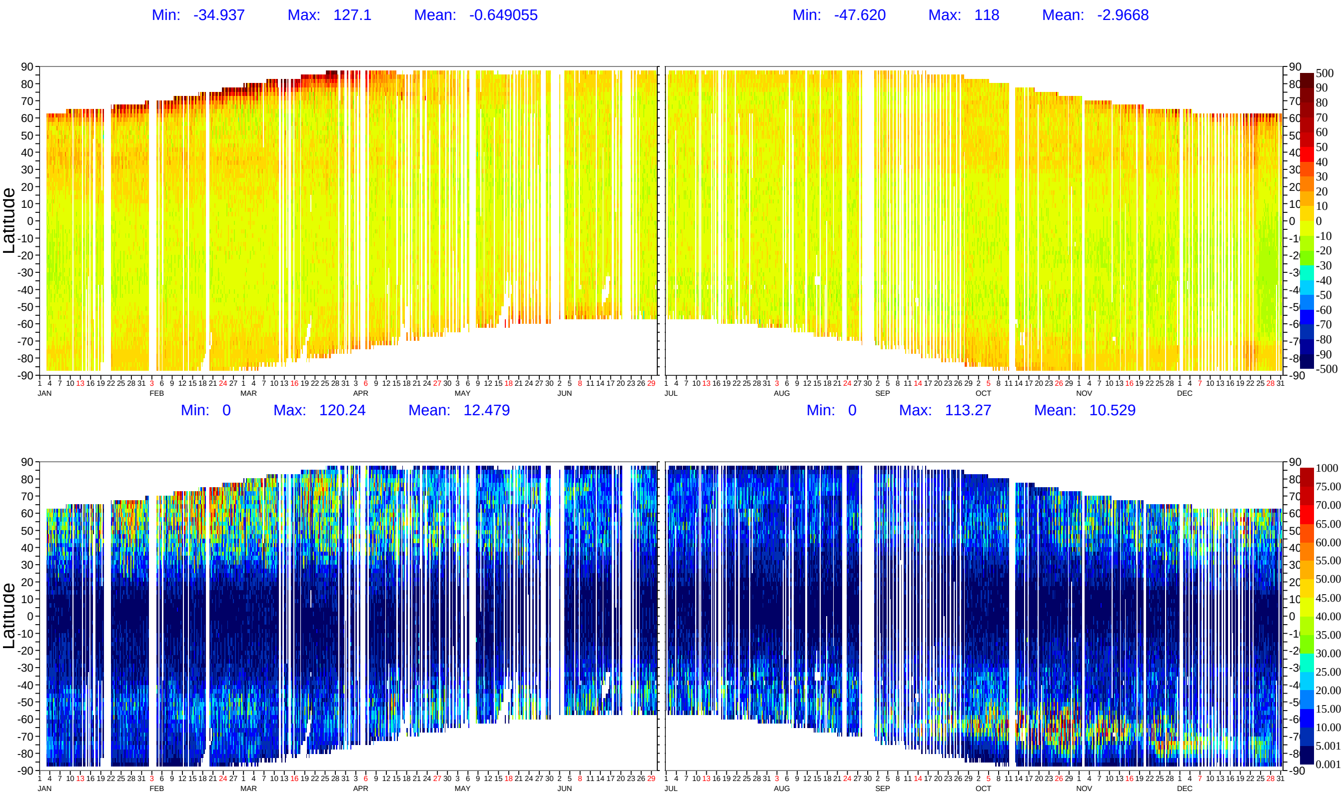


Figure 3: Time series of the zonal mean NRT SCIAMACHY first-guess departures (top panel) and of the zonal mean NRT SCIAMACHY standard deviation (bottom panel) during 2008. All ozone values are in DU.

departures for NRT SCIAMACHY TCO were found to be well within ±5 DU.

The generally good quality of the SCIAMACHY TCO was also confirmed by comparisons with independent total column ozone observations retrieved from the OMI and GOME-2 measurements. Results from these comparisons showed that the regions characterized by the largest differences in TCO between OMI and SCIAMACHY were at high latitudes near the end of the orbits.

4 Monitoring of GOMOS data

GOMOS makes use of the occultation measurement principle by tracking stars as they set behind the atmosphere. GOMOS has an ultraviolet-visible and a near-infrared spectrometer, covering the wavelength region between 250 and 950 nm. It allows the retrieval of atmospheric trace gas profiles in the altitude range 100-15 km, with an altitude resolution better than 1.7 km. GOMOS gives day- and night-time measurements with about 600 profiles per day. The primary GOMOS target species are O_3, NO_2, NO_3, OClO, H_2O and temperature (fixed to the ECMWF temperature forecasts in v5.00).

A subset of these retrieved products that is available in NRT (GOM_RR__2P) is routinely and passively monitored at ECMWF. This subset includes temperature, water vapour and ozone profiles.

The data availability was generally continuous during the whole 2008. During the period from 4 to 23 June, the monitoring of the temperature could not be performed because of technical problems that arose after the cycle CY33R1 was switched on (4 June 2008). These technical problems did not affect the monitoring of neither the ozone nor the water vapour products. Figure 7 shows the time series of the global number of GOMOS

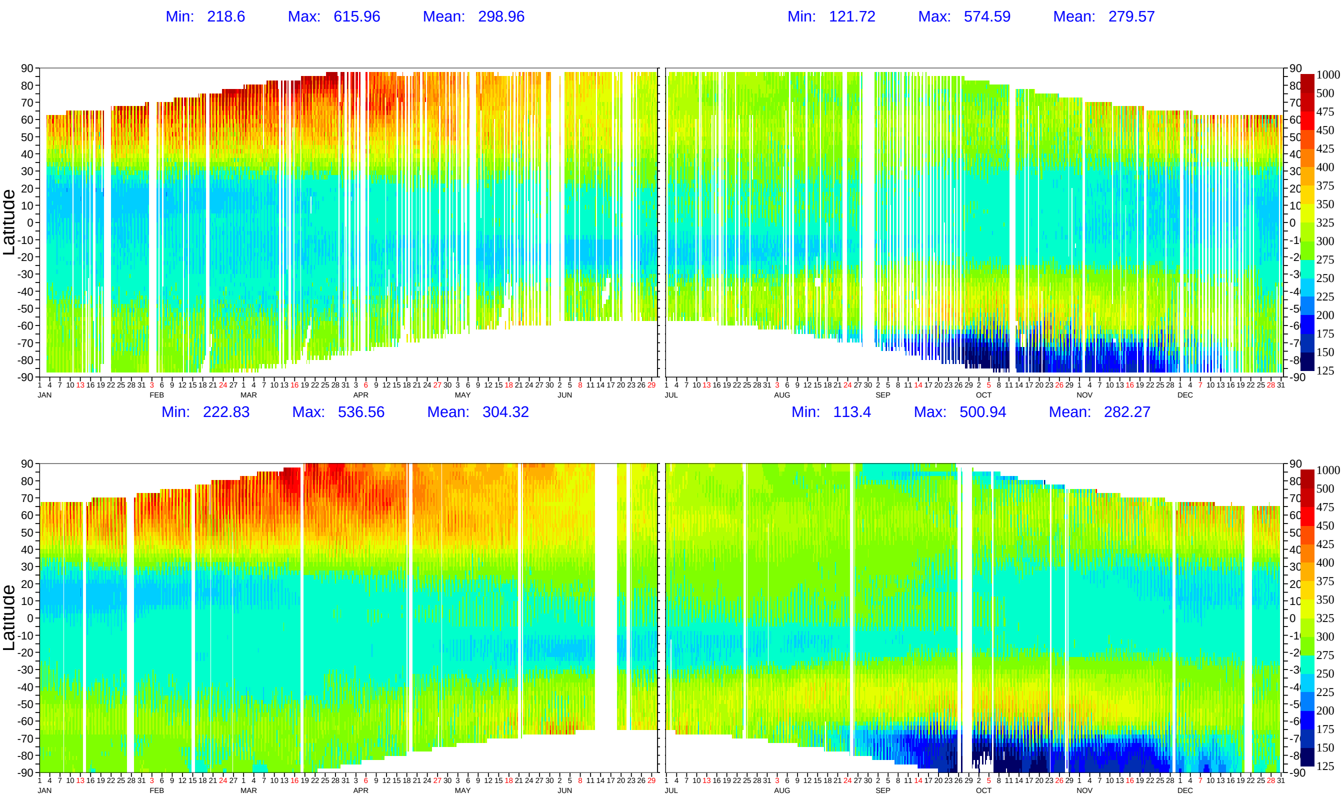


Figure 4: Time series of the zonal mean NRT SCIAMACHY ozone (top panel) and OMI total column ozone (bottom panel) for 2008. All ozone values are in DU.

temperature observations (top) and of the zonal mean GOMOS temperature (bottom) during 2008, respectively. In particular, the bottom panel of figure 7 shows that a large number of observations were discarded in the NH during 2008, as result of the data filtering implemented in the BUFR converter[6] in May 2007 (Dragani, 2008).

4.1 Monitoring of GOMOS temperature data

The quality of the temperature profiles in the BUFR files was stable during 2008, and consistent with the temperature data retrieved in 2007 (Dragani, 2008).

With the implementation of IFP 5.0 on August 2006, the GOMOS temperature was no longer retrieved. The information provided in the BUFR files was instead derived as the "Tangent Point Temperature from External Model" stored in the GAD. This means that the *temperature profile* is *obtained by the combination of the ECMWF 24 hour temperature forecast in the lower part of the profile up to 1 hPa*[7] *and of the MSIS90 data in the upper part of the profile (smooth transition altitude range around the pressure level 1hPa)* (ESA, 2007).

Figures 8 and 9 show the comparisons between area averaged GOMOS and ECMWF temperature profiles (left panel) and GOMOS temperature departures (right panel) for the periods 1 April to 30 June (AMJ) and 1 September to 30 November 2008 (SON), respectively. In both figures, the top panels refer to the tropics

[6] The data sampled in bright, twilight or straylight limb conditions are discarded as they are of poor quality and not suited for scientific studies. See the GOMOS quality disclaimer available at `http://envisat.esa.int/dataproducts/availability/disclaimers/` and Meijer et al. (2004) for more information.

[7] The ECMWF forecasts and analyses were only available up to 1 hPa.

(30°N-30°S), the middle panels refer to the midlatitudes in the SH (30°-60°S), and the bottom panels refer to the high latitudes in the SH (60°-90°S).

Both figures 8 and 9 show that, in general, the temperature profiles in the BUFR files are lower than their model equivalent. In particular, the first guess and analysis departures were typically up to about -1% (-2 K) in all the stratosphere in the tropics, and within ±1% at the other latitudinal bands in the stratosphere. Larger first guess and analysis departures were found in the mesosphere, as the temperature profiles were relaxed to the MSIS90 data, with differences up to about -4% (-8K) between 0.2 and 0.4hPa.

The timeseries of the global mean temperature data and their departures also confirm the level of agreement discussed above between the temperature data in the GOMOS files and the ECMWF temperature analyses. An example that refers to the 20 hPa pressure level is displayed in figure 10.

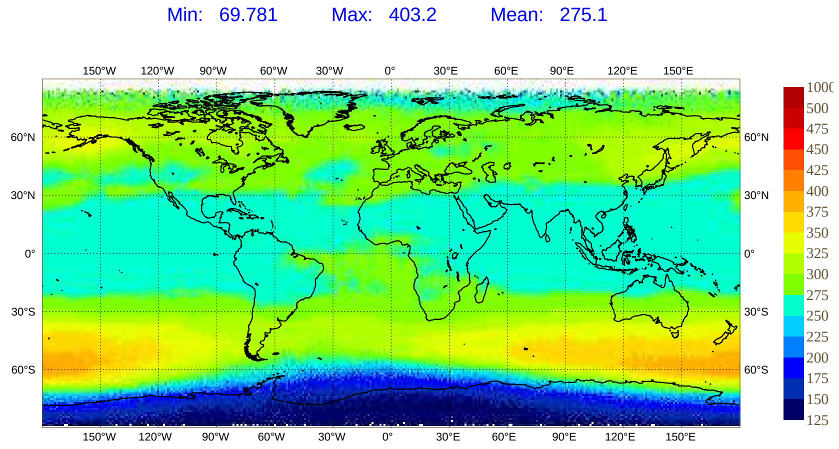
4.2 Monitoring of GOMOS ozone data

This section discusses the results from the monitoring of the NRT GOMOS Level 2 ozone profiles in 2008.

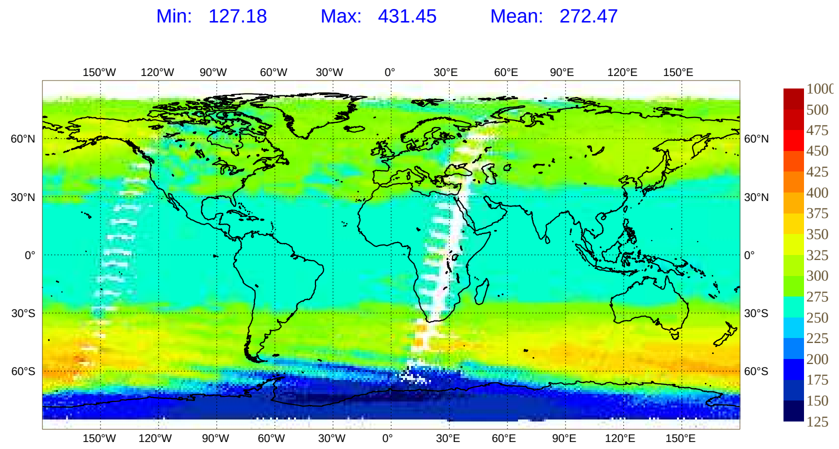
Figure 11 presents the comparisons between the global mean GOMOS ozone profiles and the global mean ECMWF ozone first-guess and analysis, averaged over the whole 2008. In the global mean, the agreement between the GOMOS ozone observations and their model equivalent is better than the GOMOS one standard deviation limit at all vertical levels. The GOMOS ozone values are usually smaller than their model equivalent in the middle stratosphere (typically between 4 and 20hPa), and larger elsewhere. The global mean first-guess and analysis departures are within -5 and +20% in most of the stratosphere (for pressure values smaller than 40hPa) and mesosphere, but larger departures were found in the lower stratosphere (for pressure values larger than 40hPa), and in the mesosphere between 0.1 and 0.2hPa. The standard deviations of the departures were found to be larger than 15% in the lower stratosphere and larger than 50% in the upper stratosphere and mesosphere.

Figure 12 shows the 2008 global mean time series of the observations and their model equivalent (top panel), of the first-guess and analysis departures (middle panel), and of their standard deviations (bottom panel) for the vertical layer between 20 and 40 hPa, which corresponds roughly to the layer where ozone peaks. From the time series in figure 12, GOMOS observations exhibit higher ozone values than the ECMWF ozone analyses, with mean differences in that layer within 4 to 16 DU during 2008. Large standard deviations up to 20 DU were found in the data, corresponding to just below 25% of the annual mean ozone value in this layer.

When averaging over latitudinal bands, the level of agreement just discussed is usually confirmed. Figures 13 and 14 show the area averaged GOMOS ozone profiles (left hand side panels) and GOMOS departures (right hand side panels) for three latitudinal bands and averaged over the period April to June (AMJ), and September to November 2008 (SON), respectively. In both figures, the top panels refer to the tropics (30°N-30°S), the middle panels refer to the midlatitudes in the SH (30°-60°S), and the bottom panels refer to the high latitudes in the SH (60°-90°S). Because of the filter implemented to remove poor quality data, the number of observations retained in the extratropics in the NH, if present at all, were too low to be statistically significant.



(a)



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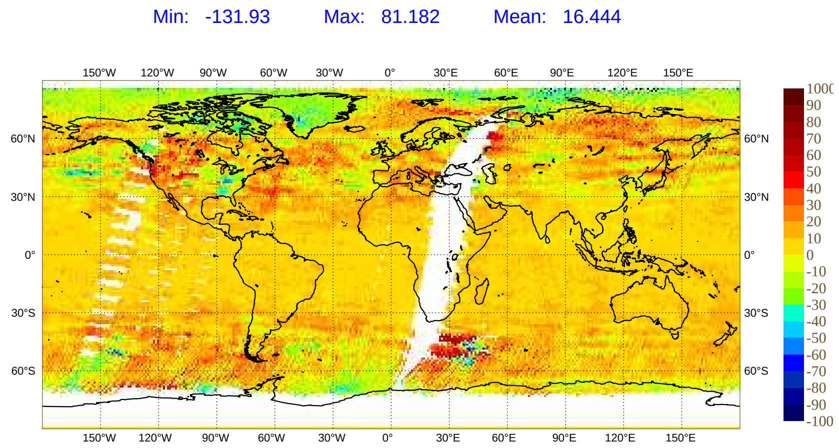


(c)

Figure 5: Geographical distribution of monthly mean OMI TCO (top), monthly mean SCIAMACHY TCO (middle), and their difference (bottom) for October 2008. Values are in DU.

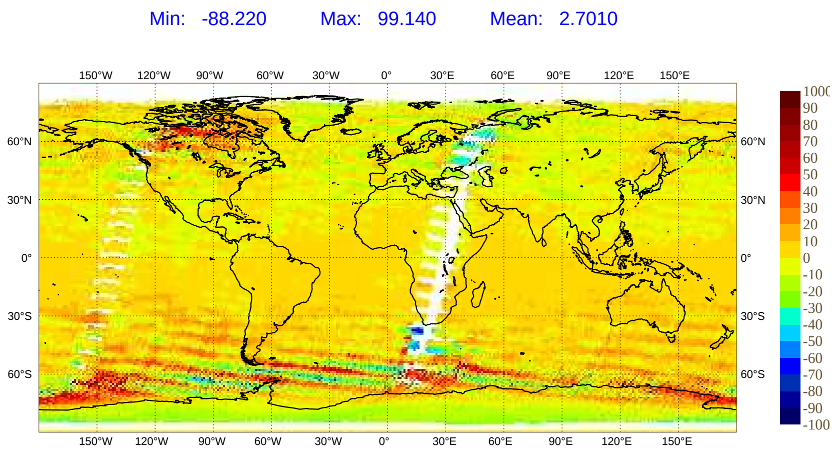


Figure 6: Geographical distribution of monthly mean difference between GOME-2 TCO and SCIAMACHY TCO for October 2008. Values are in DU.

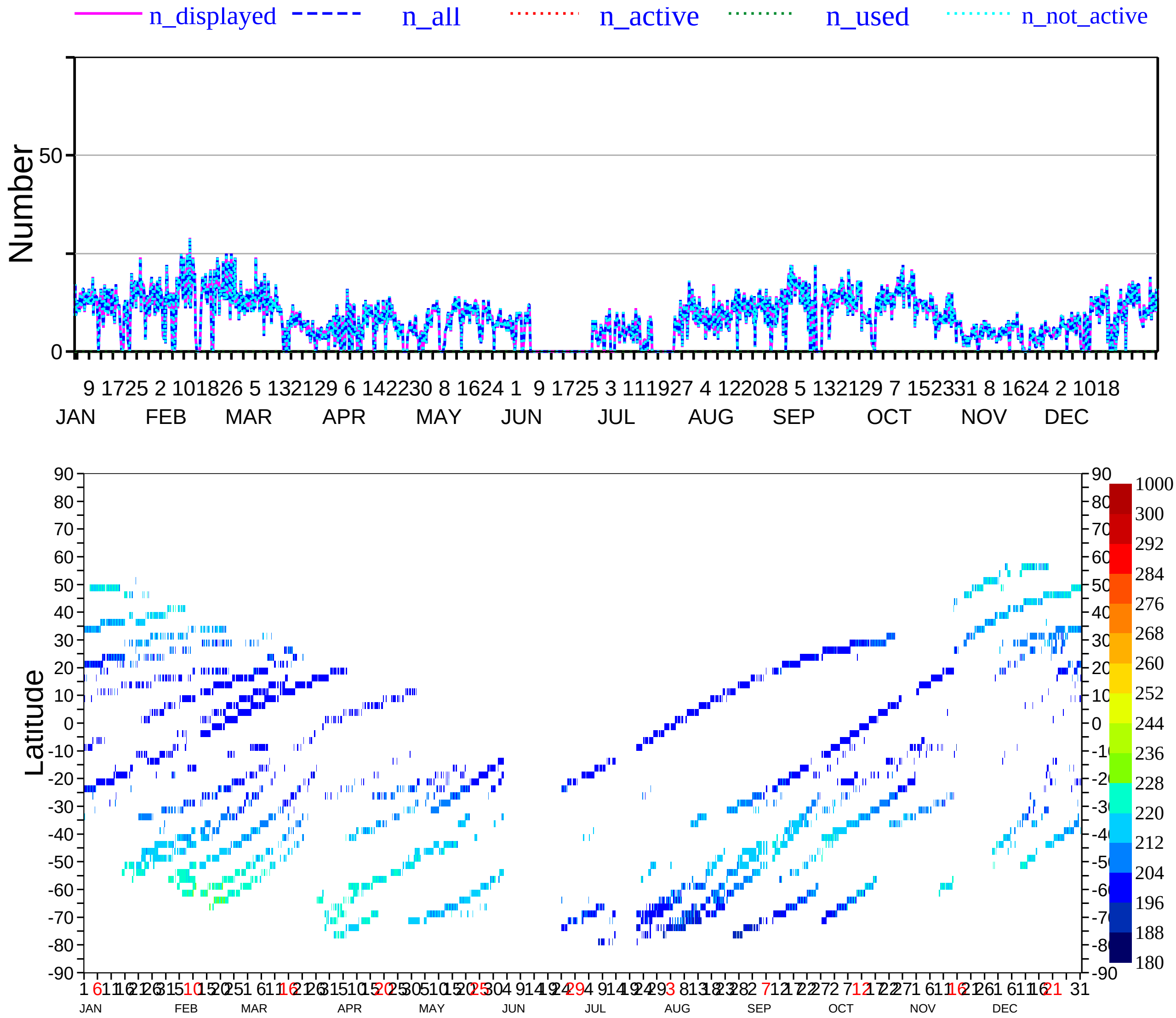


Figure 7: Time series of the global number of GOMOS temperature observations (top panel) and of the zonal mean number of GOMOS temperature observations (bottom panel) during 2008.

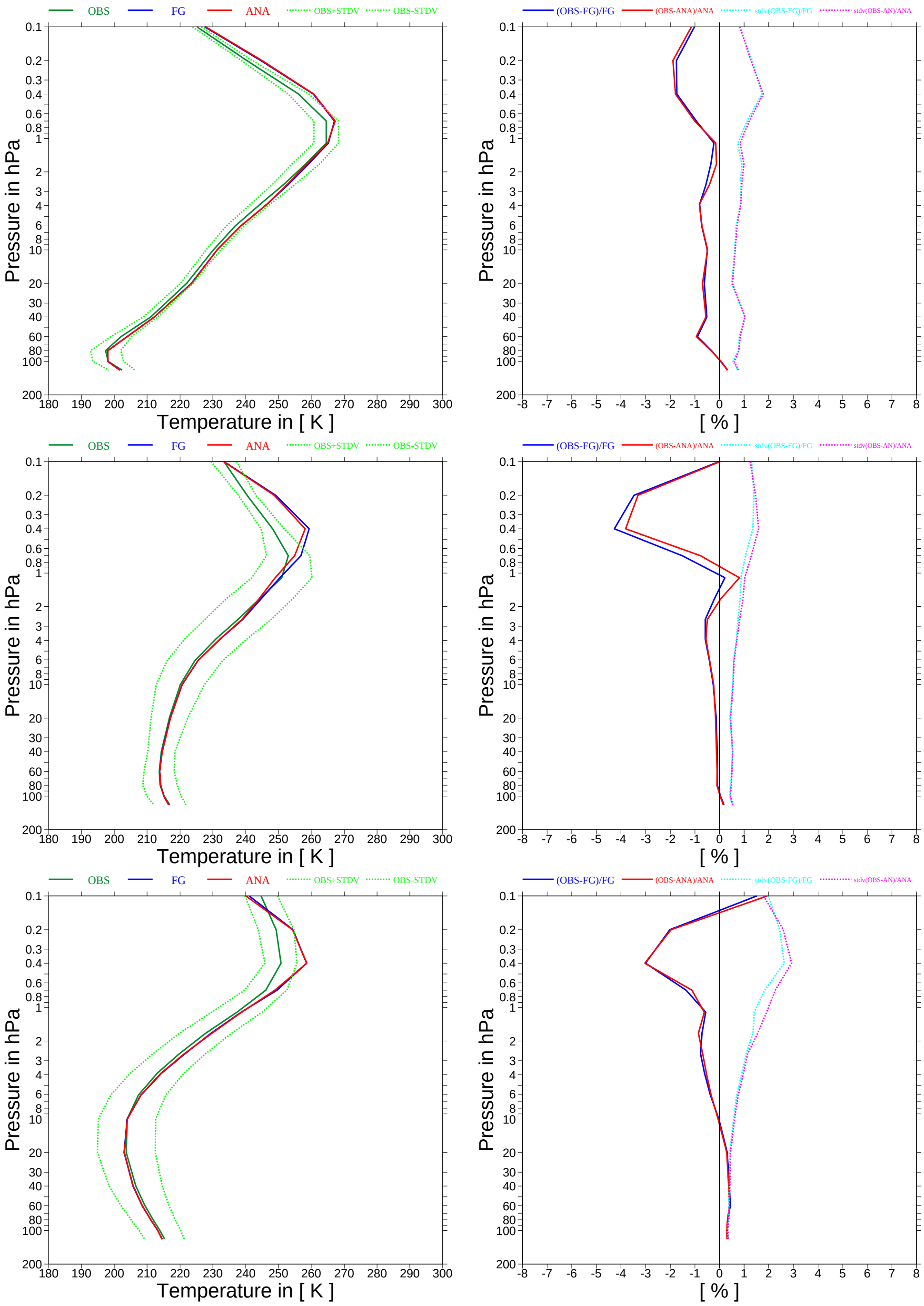


Figure 8: Comparisons between the area averaged temperature extracted from the GOMOS files and the area averaged ECMWF temperature first-guess and analysis. Right panels refer to the profile comparisons, left panels show the relative first-guess and analysis departures. The averaging period is between April and June 2007. The top panels refer to the tropical band 30°N-30°S, the middle panels refer to the midlatitudes in the SH (30°-60°S), and the bottom panels refers to the high latitudes in the SH (60°-90°S). Temperature values are in K, departures are in %.

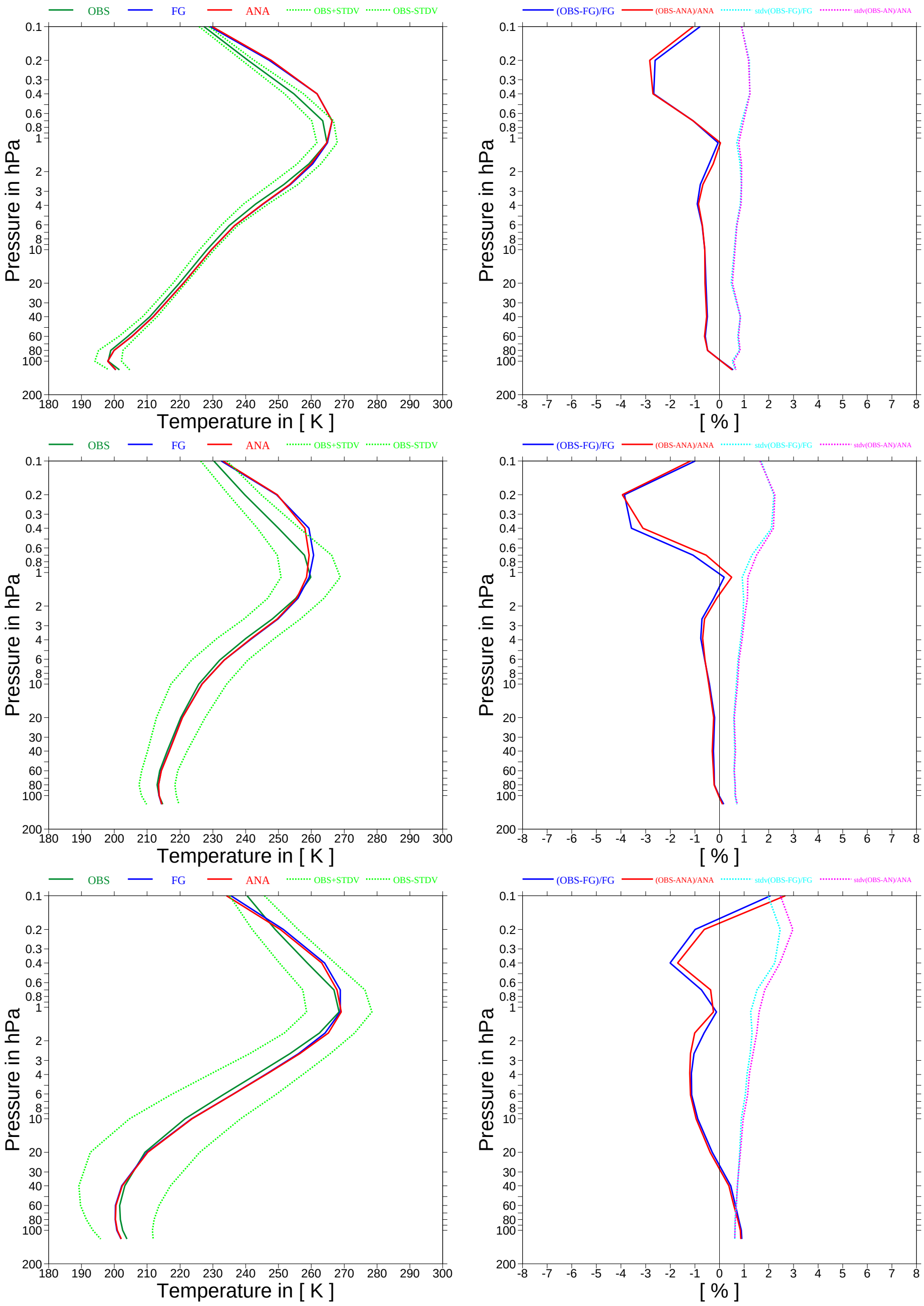


Figure 9: Like in figure 8, but the averaging period is between 1 September and 30 November 2008.

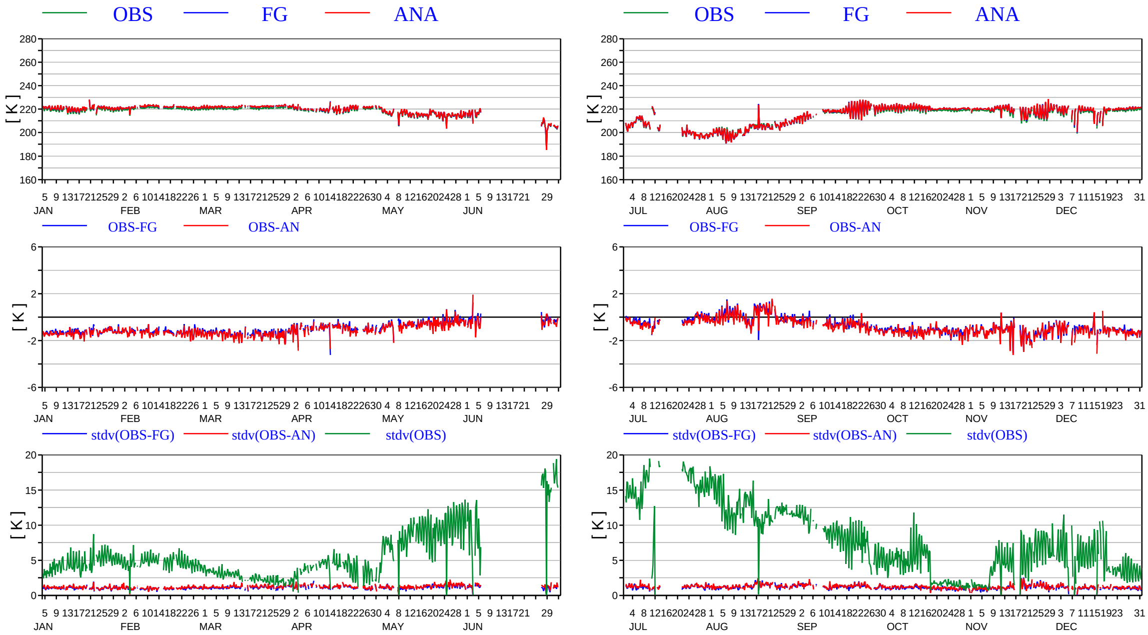


Figure 10: Timeseries of globally averaged data at 20 hPa covering the periods 1 January to 30 June (left panel), and 1 July to 31 December 2008 (right panel). The top panels of each figure show GOMOS NRT total temperature observations, first-guess and analysis values, while the middle panels refer to the first-guess and analysis departures. All temperature values are in K.

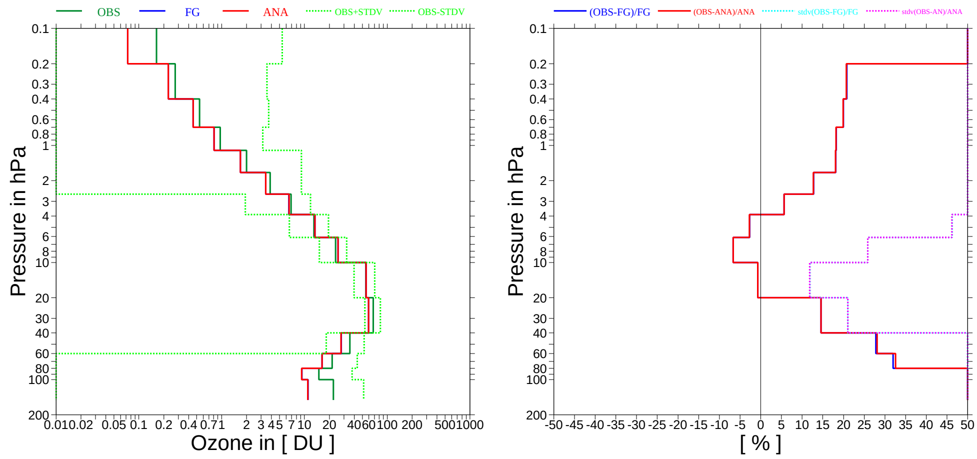
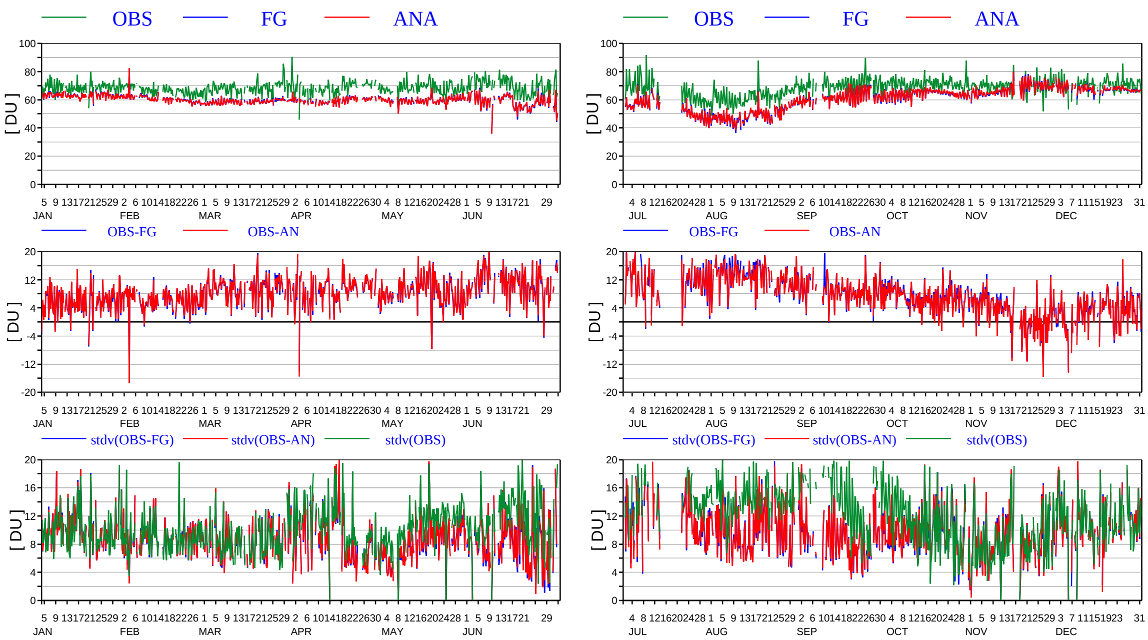


Figure 11: Comparisons between the annual mean global mean GOMOS ozone profiles and the area averaged ECMWF ozone first-guess and analysis. Right panels refer to the profile comparisons, left panels show the relative first-guess and analysis departures. Ozone values are in DU, departures are in %.

In both periods, the agreement between the GOMOS ozone observations and their model equivalent is better than the GOMOS one standard deviation at all vertical levels and available latitudinal bands. The largest differences are found in the lower stratosphere, typically for pressure values larger than 40 hPa, and in the upper mesosphere where the first-guess and analysis departures can be larger than 50% in places. Also the first-guess and analysis departure standard deviations are very large with values larger than 50% in places, an indication of large noise in the ozone retrievals. During the period SON, some improvements were seen in the tropics (top panels of figure 14) in the upper stratosphere and at mesospheric levels compared with the same latitudinal band during AMJ (top panels of figure 13).



(a) (b)

Figure 12: Timeseries of globally averaged data covering the periods (a) 1 January to 30 June, and (b) 1 July to 31 December 2008 at 20-40 hPa. The top panels of each figure show GOMOS NRT partial column ozone, first-guess and analysis values, the middle panels first-guess and analysis departures and the bottom panels the standard deviations of GOMOS ozone data and of first-guess and analysis departures. All ozone values are in DU.

The presence of large noise in the data is also illustrated by the scatter plots of GOMOS ozone data and its first-guess departures for the layer 20-40 hPa (figure 15). Figure 15(a) refers to the period from 1 to 30 April 2008, while figure 15(b) refers to the period from 1 to 31 October 2008. The panels on the left show the scatter plots of the observations versus latitude, those on the right show the scatter plots of the first-guess departures versus latitude. The relatively large scatter in the observations against the latitudes leads to a large scatter in the first-guess departures as well, with variability within -30 and +40 DU in both cases. A few outliers were also seen in the scatter plots.

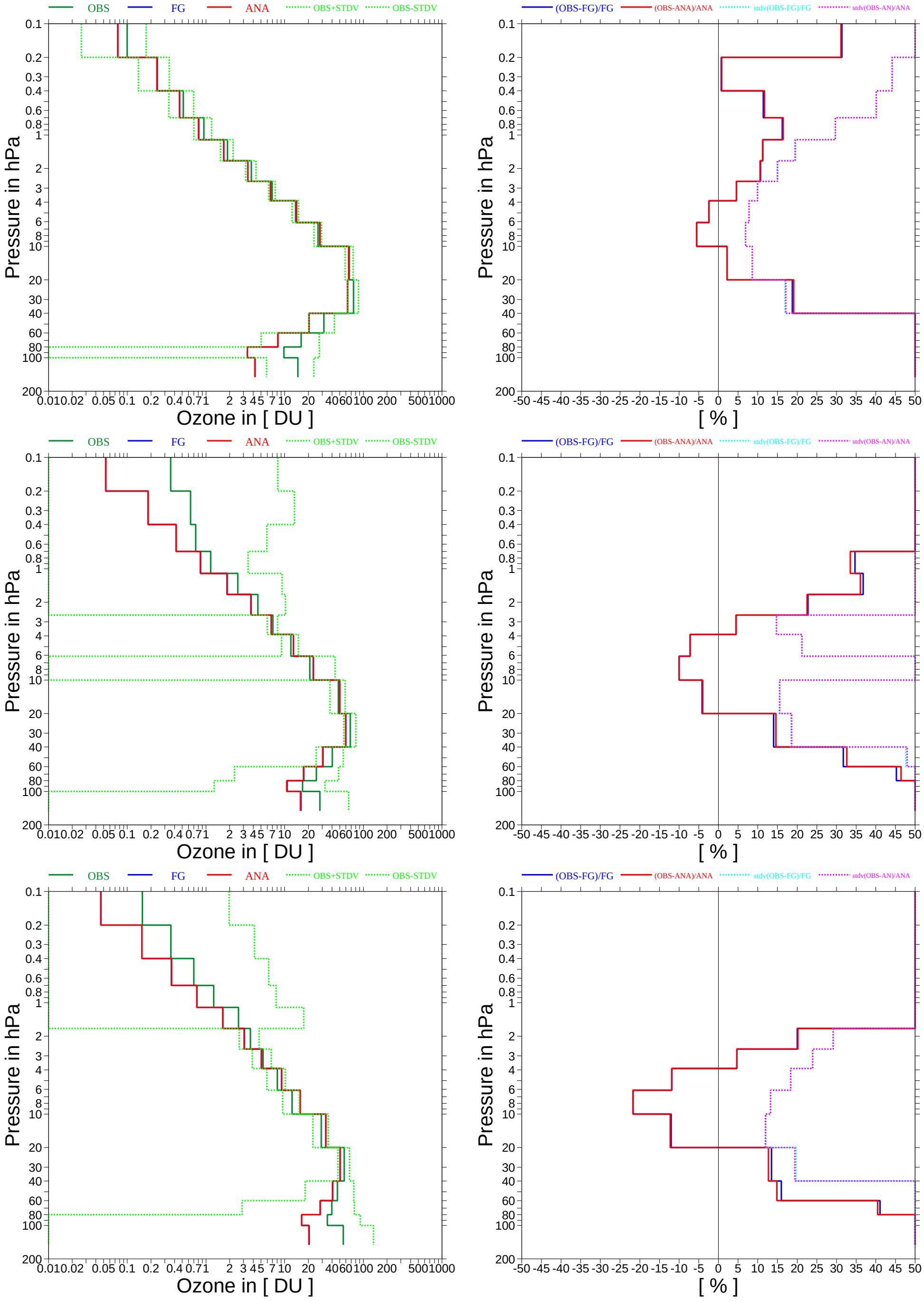


Figure 13: Like in figure 8, but for ozone. Ozone values are in DU, departures are in %.

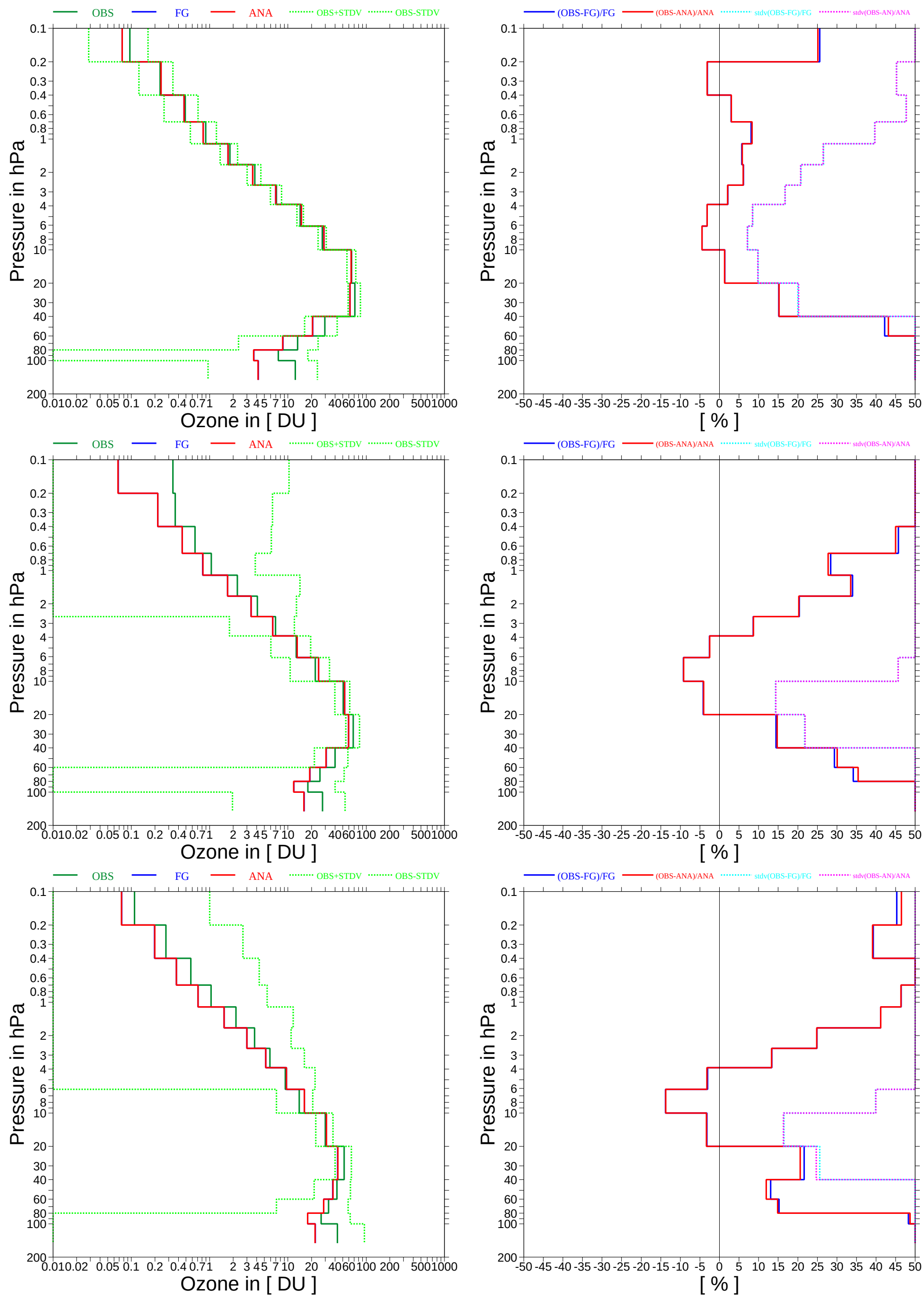


Figure 14: Like in figure 13, but the averaging period is between 1 September and 30 November 2008.

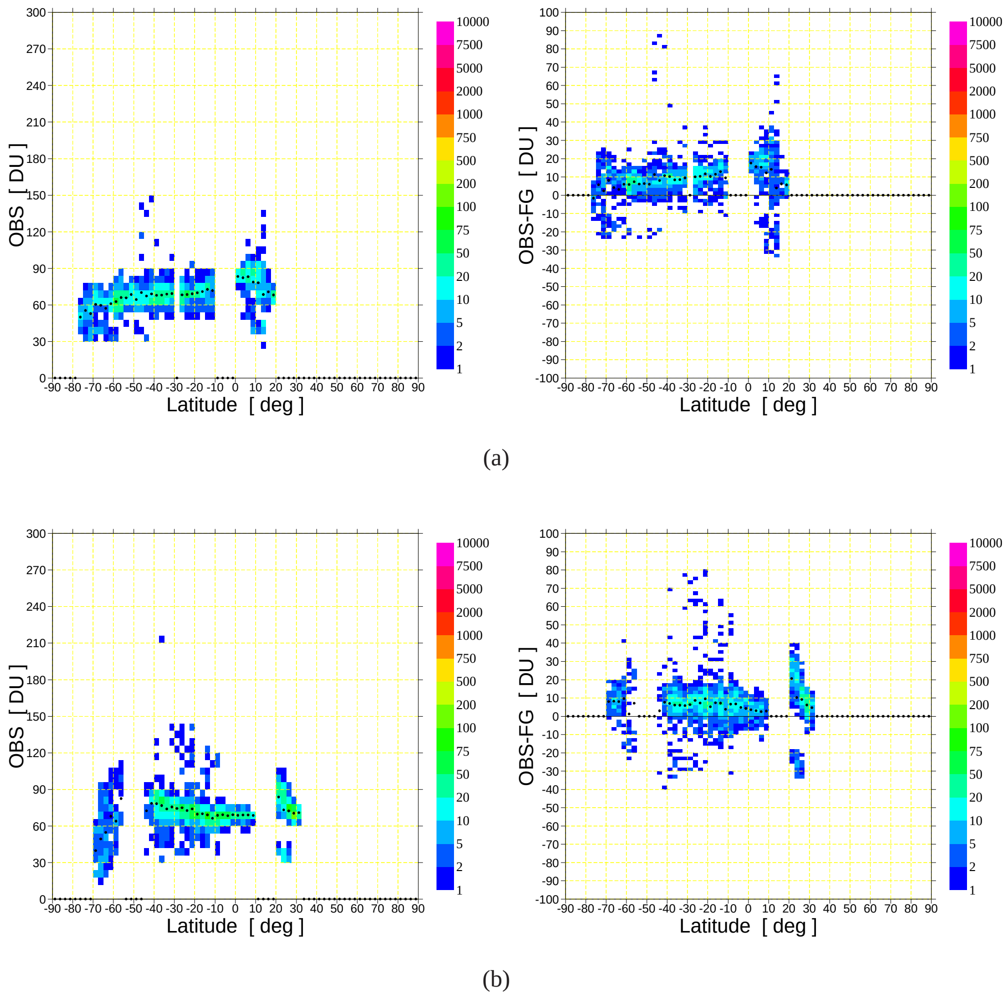


Figure 15: *Scatter plots of NRT GOMOS ozone (left) and of NRT GOMOS ozone first-guess departures (right) in the layer 20-40 hPa plotted against latitude, for the periods April 2008 (panels [a]) and October 2008 (panels [b]). The colours give the number of observations per bin, and the black dots the mean per bin. All ozone values are in DU.*

4.3 Monitoring of GOMOS water vapour data

The NRT GOMOS data were available in the GOM_RR__2P BUFR files for the whole 2008. However, the quality of the water vapour data was poor.

Figure 16 shows two examples of comparisons between the monthly mean area averaged GOMOS water vapour profiles (the green lines) with their model equivalent at three latitudinal bands during April (l.h.s. panels) and October (r.h.s. panels) 2008, respectively (see figure caption for details). These profile plots show that the GOMOS water vapour values were from one to four orders of magnitude larger than those given by the model at all stratospheric levels. The largest differences were found in the upper stratosphere, where not only did the GOMOS observations exhibit on average values of four order of magnitudes larger than their model equivalent, they also were larger than the mean GOMOS tropospheric observation.

The poor level of agreement between the GOMOS water vapour profiles and their model equivalent is also shown in the scatter plots presented in figure 17 for the integrated layer between 1 and 100 hPa. The two panels show the scatter plot for April (l.h.s. panel) and October (r.h.s. panel) 2008, respectively.

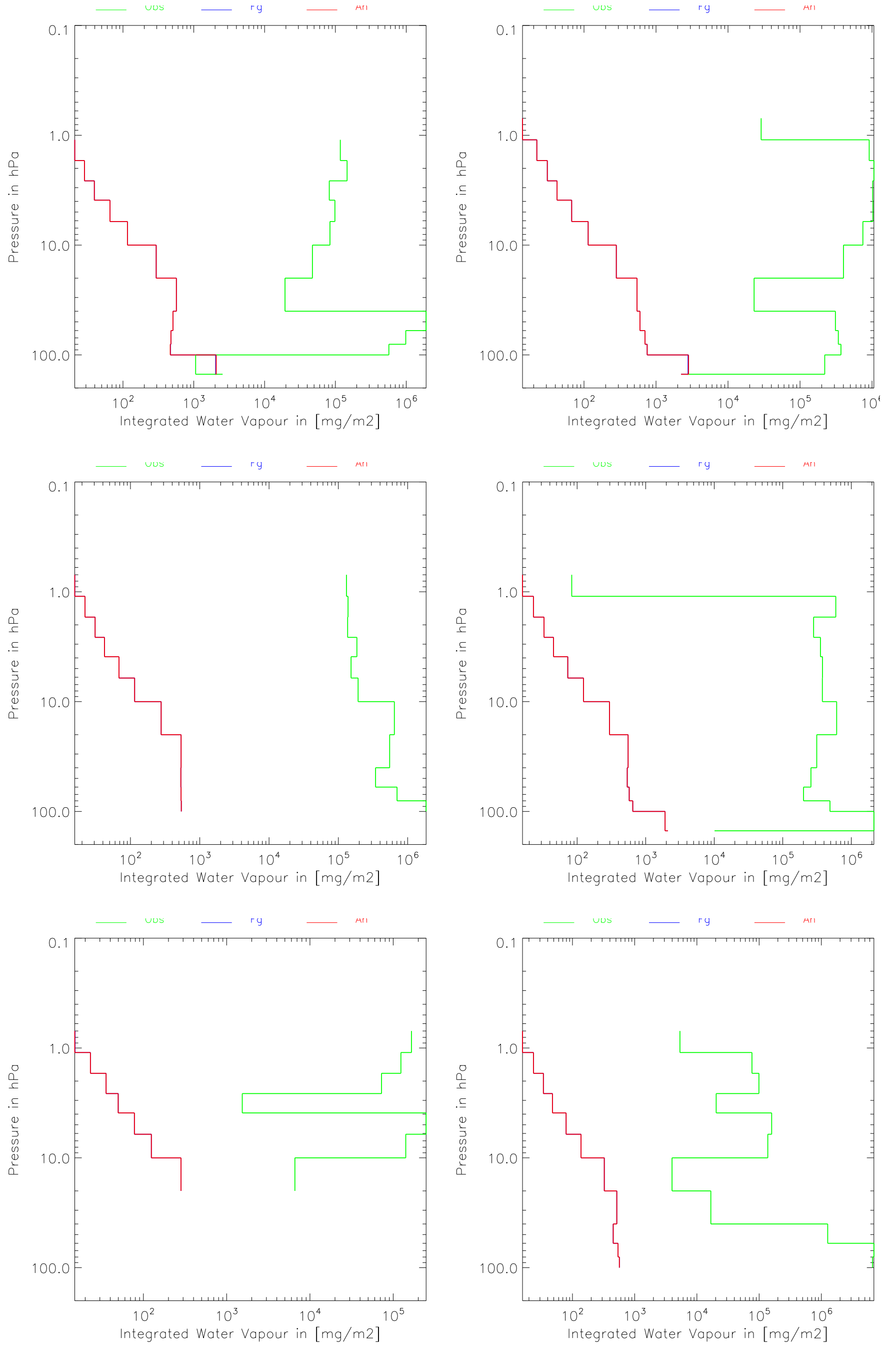


Figure 16: Comparisons between the area averaged GOMOS water vapour profiles and the area averaged ECMWF water vapour first-guess and analysis for April 2008 (l.h.s. panels) and October 2008 (r.h.s. panels). Top panel refers to the latitudinal band 30°N-30°S, the mid panel refers to the band ([30°-60°S]), and panels [c] refers to the latitudinal band between 60° and 90°S. Water vapour values are in mg/m^2.

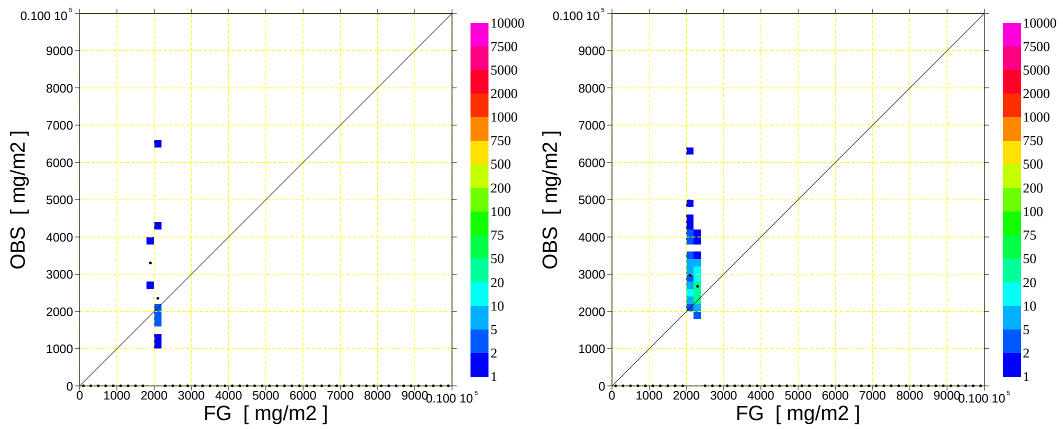


Figure 17: Scatter plots of NRT GOMOS water vapour content against the ECMWF first-guess in the integrated layer 1-100 hPa for the periods April (left), and October 2008 (right). The colours give the number of observations per bin, and the black dots the mean per bin. Values are in mg/m^2.

4.4 Monitoring of new filtered GOMOS data

As shown in section 4, the quality of the operational GOMOS retrievals, in particular the water vapour, was not particularly high compared with their model equivalent, despite the operational GOMOS data were obtained as a filtered subset of the original retrievals in which only the data sampled in full dark conditions were used. As a consequence, the GOMOS ESL did process a number of months only taking into account the brightest nine stars in the infra-red spectral range at dark limb that are guaranteed to provide high quality ozone and water vapour data. The output was produced in the same format of the operational GOMOS Meteo Product format.

These new ozone and WV data were ingested in IFS and compared with their model equivalent obtained from the first-guess and analysis fields, in the same way it is routinely performed for the operational products. An account of the key points is provided below. For completeness, the monitoring plots from the operational suite are also provided for comparison. In the following plots, the identification **0001** refers to the experiment run with the operational dataset; the identification **f1a6** is used for the experiment run with the new dataset. The monitoring was performed for the four month period between September and December 2007.

4.4.1 Key points

- The filter implemented in the PDS2BUFR differs from that used by the GOMOS QWG, and the two datasets show different coverage. In particular, because of the different selection criteria between the two datasets, there were no data found at midlatitudes in the NH (30-60N) and at high latitudes in the SH (60-90S) during the whole period under study, and very limited number of data (about 15% of the data used operationally) was measured at other latitudinal bands (see figure 18 as an example).
- Ozone:
  - In the global mean, the new dataset compares better than the operational one with their model equivalent (see figures 19 and 20).
  - The standard deviations of the ozone first-guess and analysis departures are much improved with the new dataset, especially at mesospheric levels (see light blue and pink lines in figure 20).
  - The new ozone dataset shows less scatter than the operational one during the whole period under study. Figures 21 to 23) show the scatter plots in October for a mesospheric layer, a stratospheric

layer, and for the whole Stratosphere, respectively.

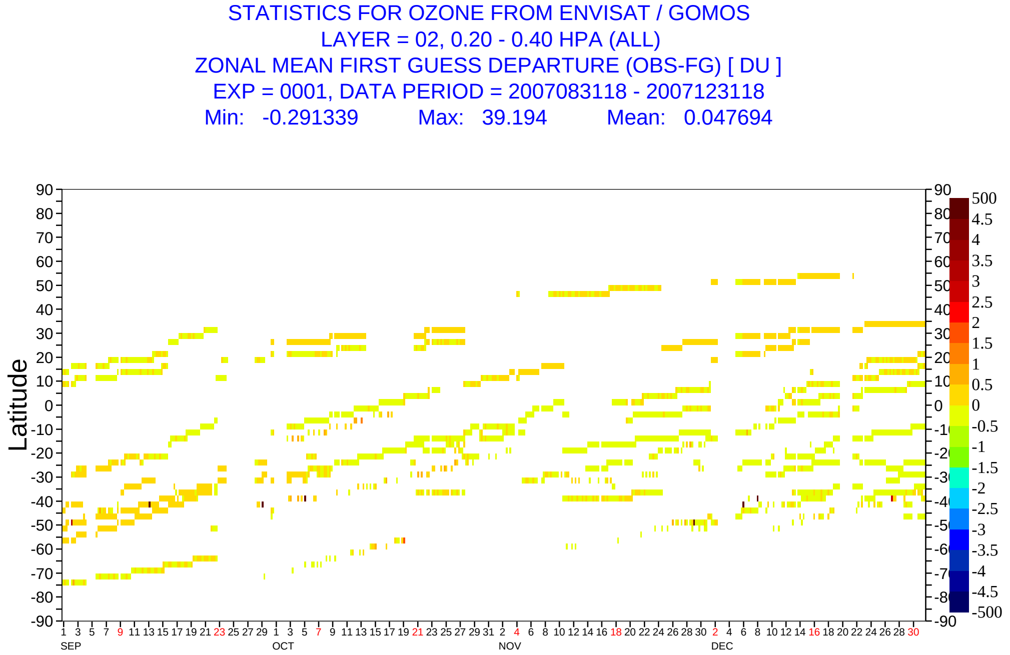
– The global mean time series plot (see figure 24) confirms that:

  1. The major differences between the two datasets are found at mesospheric layers,
  2. the number of daily observations is strongly reduced in the new dataset compared with the operational one,
  3. the new dataset show less scatter than the operational one,
  4. the standard deviations of the departures are much reduced in the new dataset compared with the operational one.

  However, figure 24 (as well as the time series plot at other levels) shows that the agreement between the GOMOS ozone observations and their model equivalent is not necessary improved by using the new dataset, except during October. The different behaviour in October compared with the rest of the period is not know. Nonetheless, it is worthwhile to point out that between 24 and 28 September, the whole ENVISAT payload was switched-off due to Service Module Anomaly (Global AOCS Surveillance triggered). It should also be pointed out that the level of agreement between the operational dataset and their model equivalent remained essentially the same before and after this anomaly.

- Water vapour:

  – Both the operational and the new datasets show higher water vapour values than their model equivalent (see figure 25).
  – The new dataset compares much better than the operational one with their model equivalent (see figure 25). While the latter generally shows that the GOMOS water vapour values were from one to four orders of magnitude larger than those given by the model at all stratospheric levels, the departures between the former dataset and their model equivalent are generally up to a few hundreds of mg/m^2, which correspond to variability within 0-2% at most levels (see figure 26).
  – The generally good level of agreement is reduced in the layer between 60 and 80 hPa in October 2007 (see figure 26).
  – Like for the ozone product, also the new water vapour data show a smaller scatter than the operational dataset (see figures 27 and 28).
  – The reduced agreement between the new GOMOS WV retrievals and their model equivalent in the layer between 60 and 80 hPa in October 2007 is also confirmed by the time series plot (see figure 29).



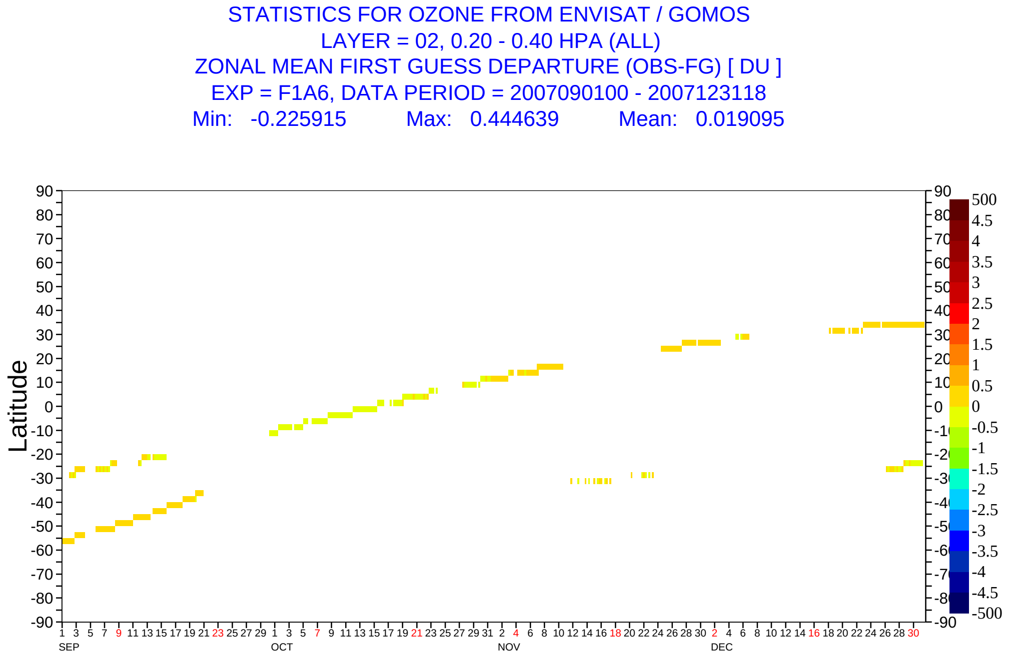


Figure 18: Hovmoeller diagram of zonal mean GOMOS first-guess departures per 6-hour cycle for September-December 2007 from the operational dataset (top panel) and the new dataset (bottom panel) for layer 2 (0.2-0.4 hPa).

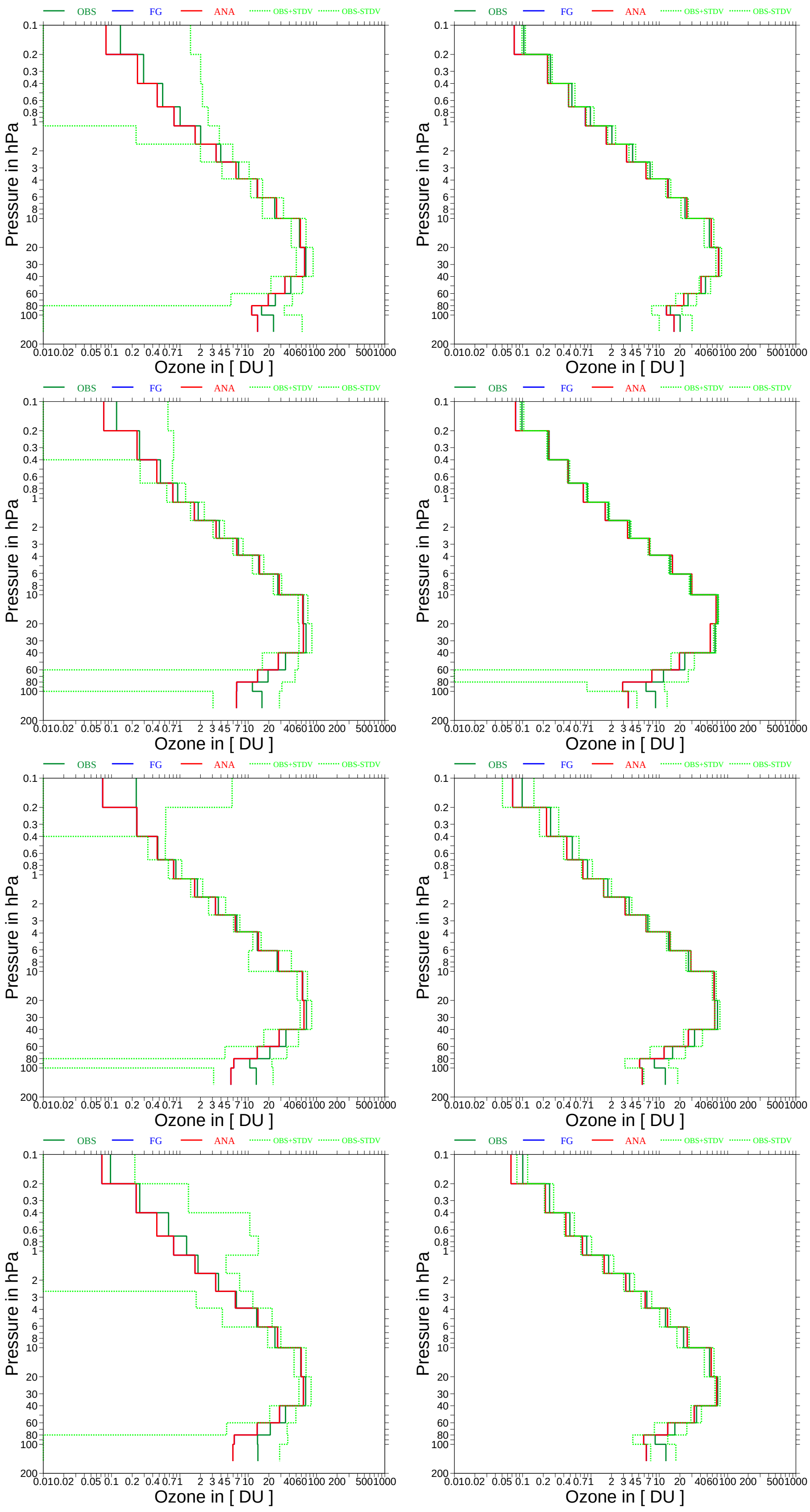


Figure 19: Comparisons between the global mean GOMOS ozone (green) and the global mean ECMWF ozone first-guess (blue) and analysis (red) for the operational dataset (right) and the new dataset (left). The light green lines limit the observation one-standard deviation range. The averaging periods are from top to bottom September, October, November, and December 2007. Values are in DU.

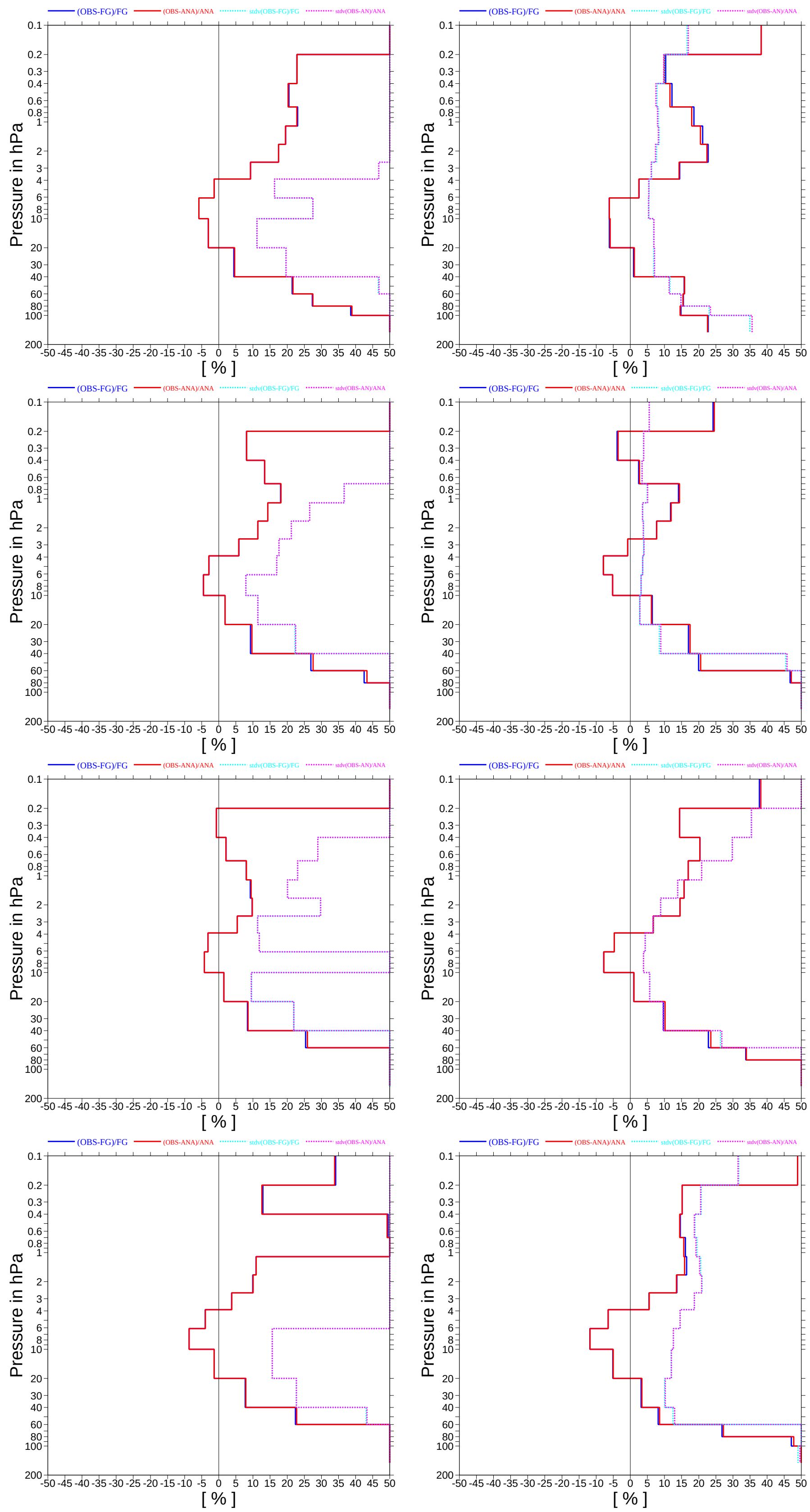


Figure 20: Like in figure 19, but for the relative first-guess (blue) and analysis (red) departures. Light blue and pink lines refer to the standard deviations of the first-guess and analysis departures, respectively. Data values are in %.

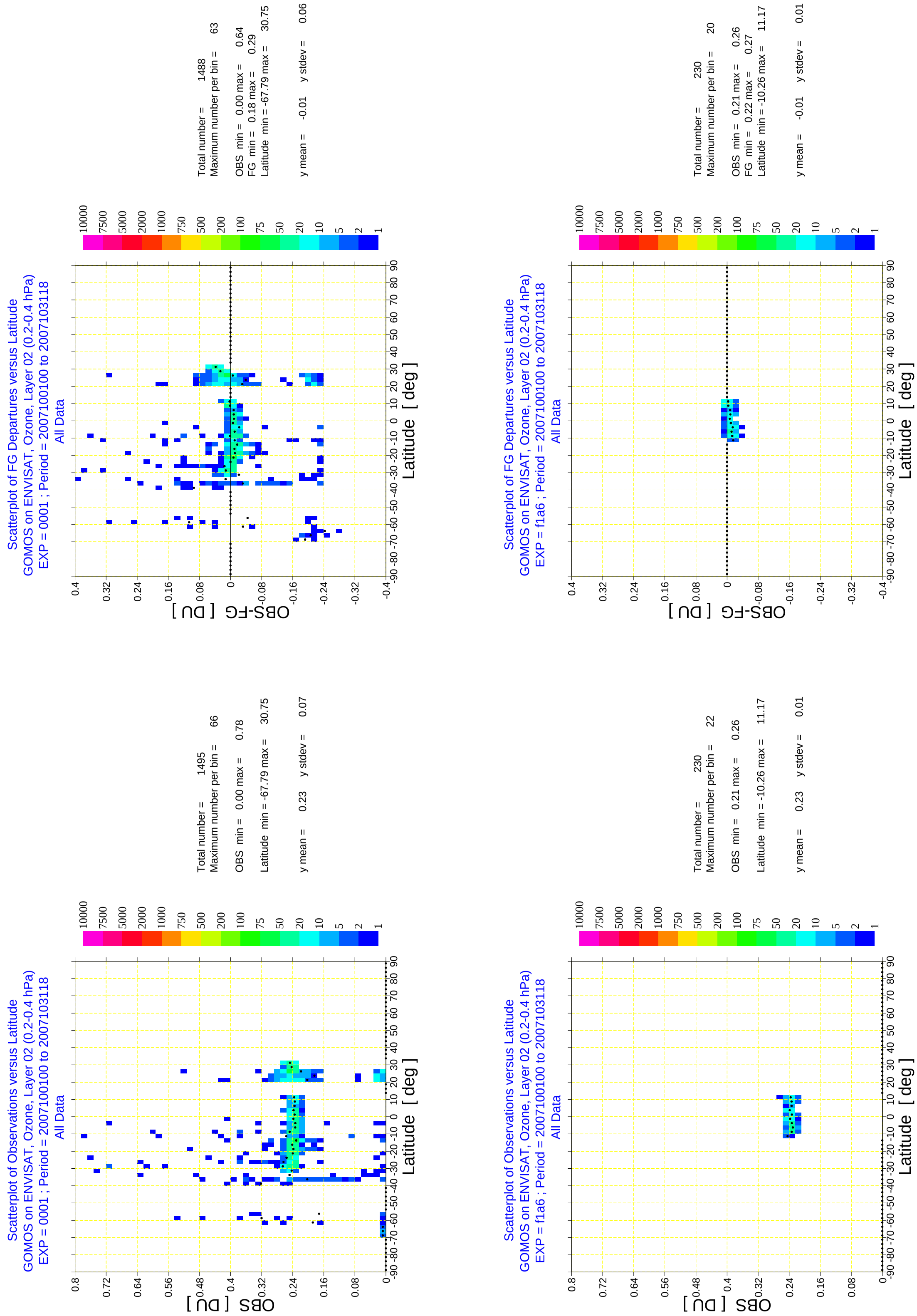


Figure 21: Scatter plots of GOMOS ozone data against latitude (left) and of their first-guess departures against latitude (right) for October 2007 from operations (l.h.s. panel) and the new dataset (r.h.s. panel). The colours show the number of data per bin, the black dots the mean value per bin.The plots refer to layer 2 (0.2-0.4 hPa).

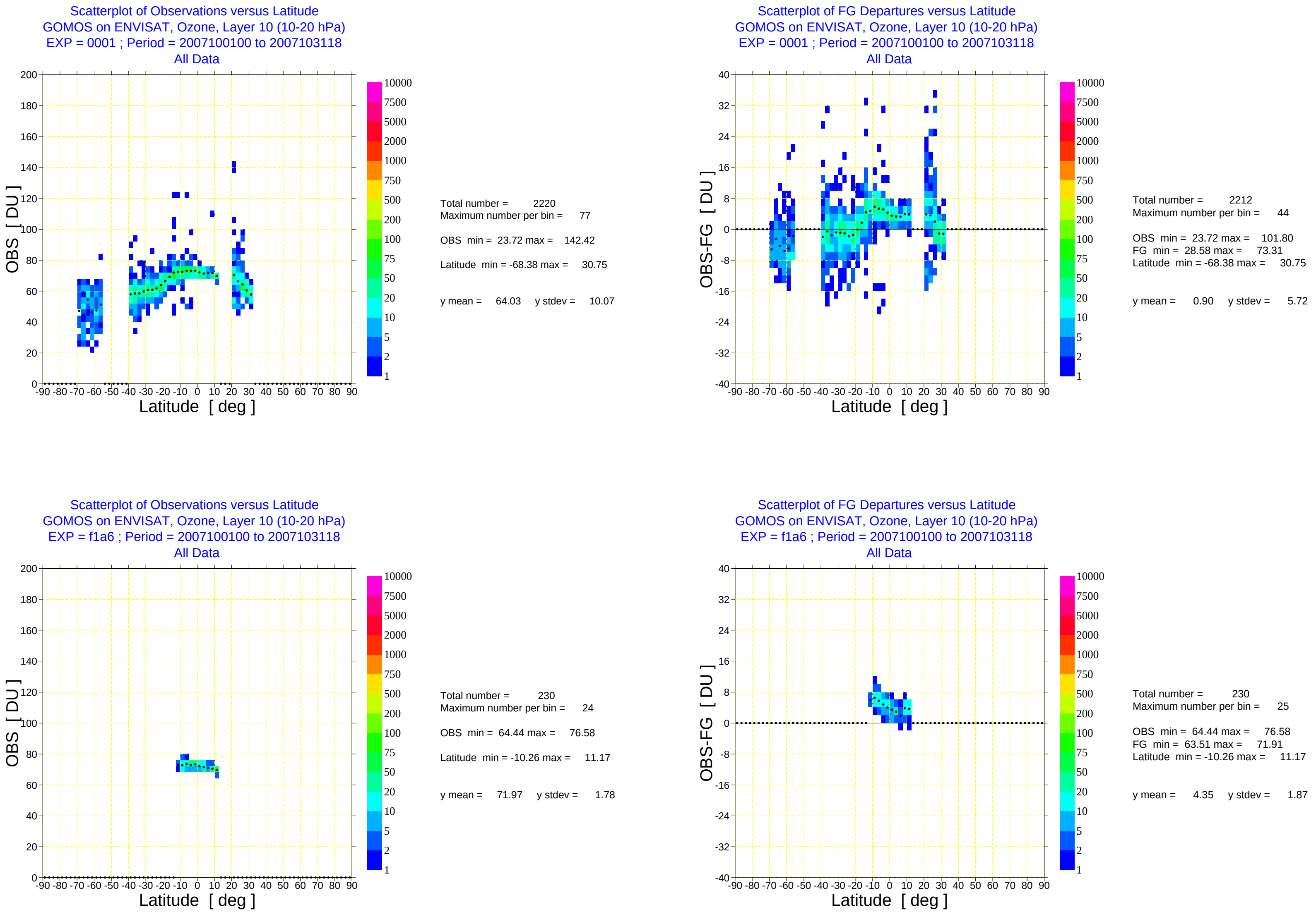


Figure 22: Like in figure 21 but for layer 10 (10-20 hPa).

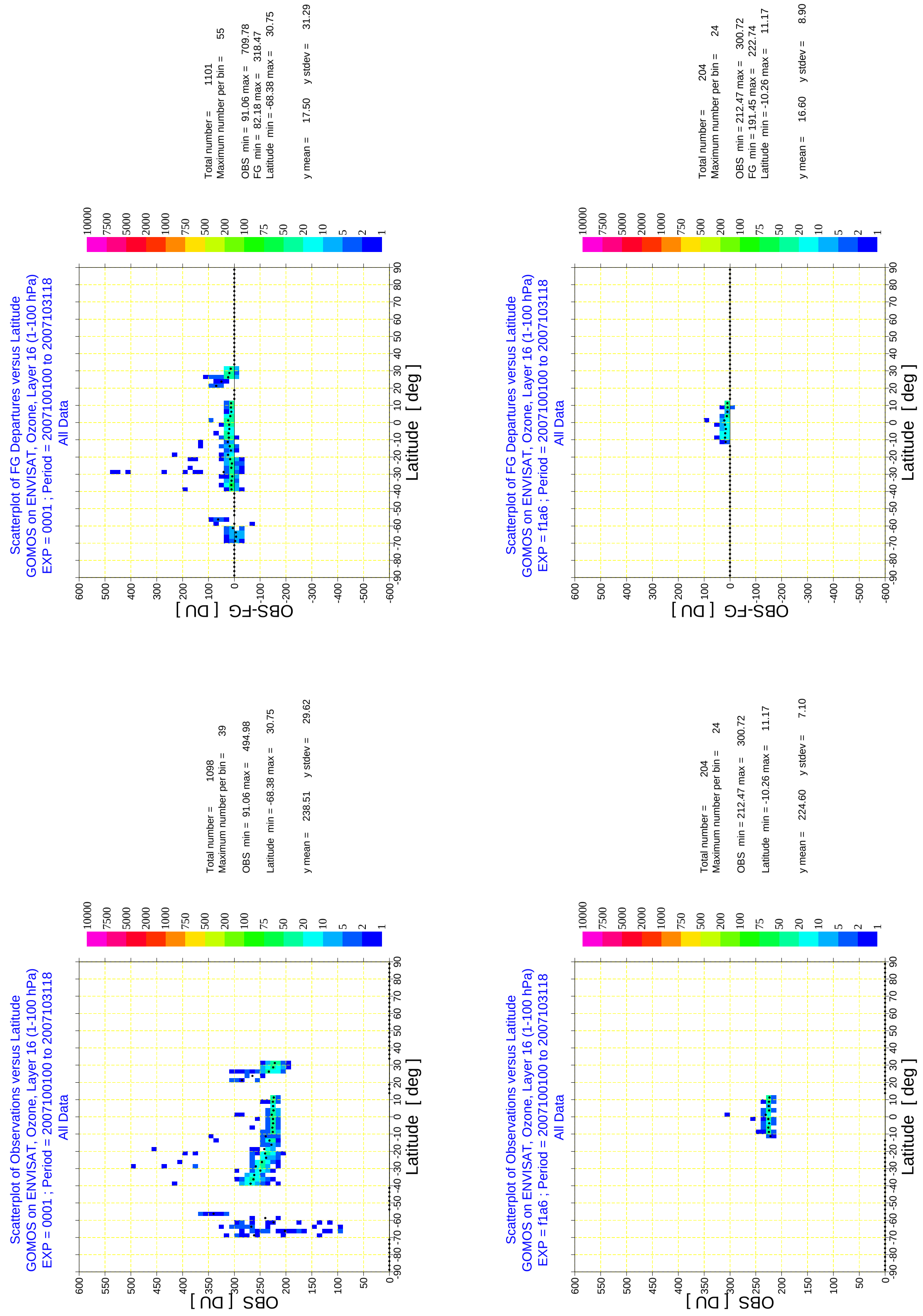


Figure 23: Like figure 21, but for layer 16 (1-100 hPa).

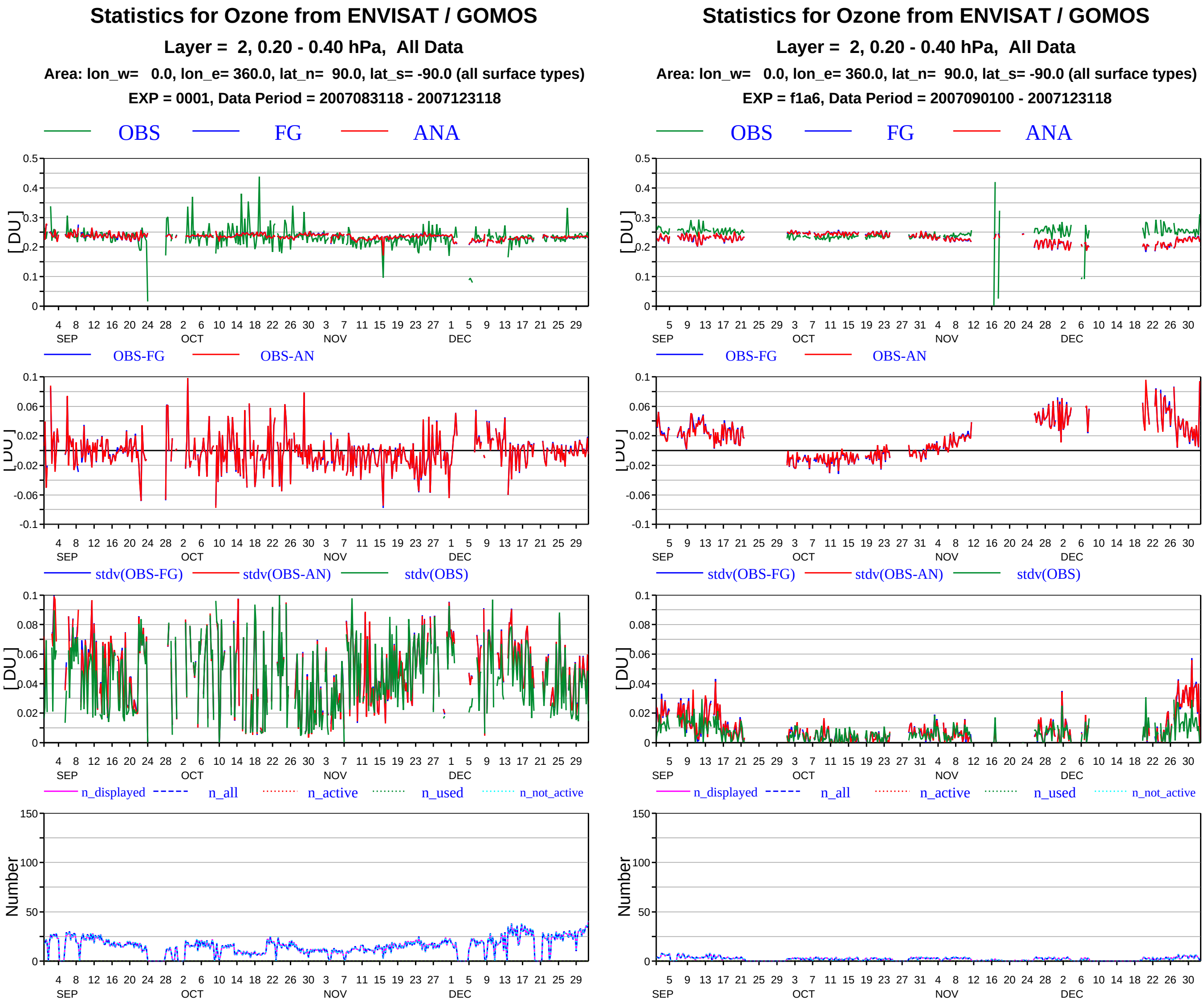


Figure 24: Timeseries of global mean ENVISAT GOMOS NRT ozone data, first guess and analysis values (top panels), first-guess and analysis departures (second panels), standard deviations (third panels) and number of data (bottom panels) per 6-hour cycle for layer 2 (0.2-0.4 hPa) for the operational set (l.h.s. panels) and the newly generated data (r.h.s. panels).

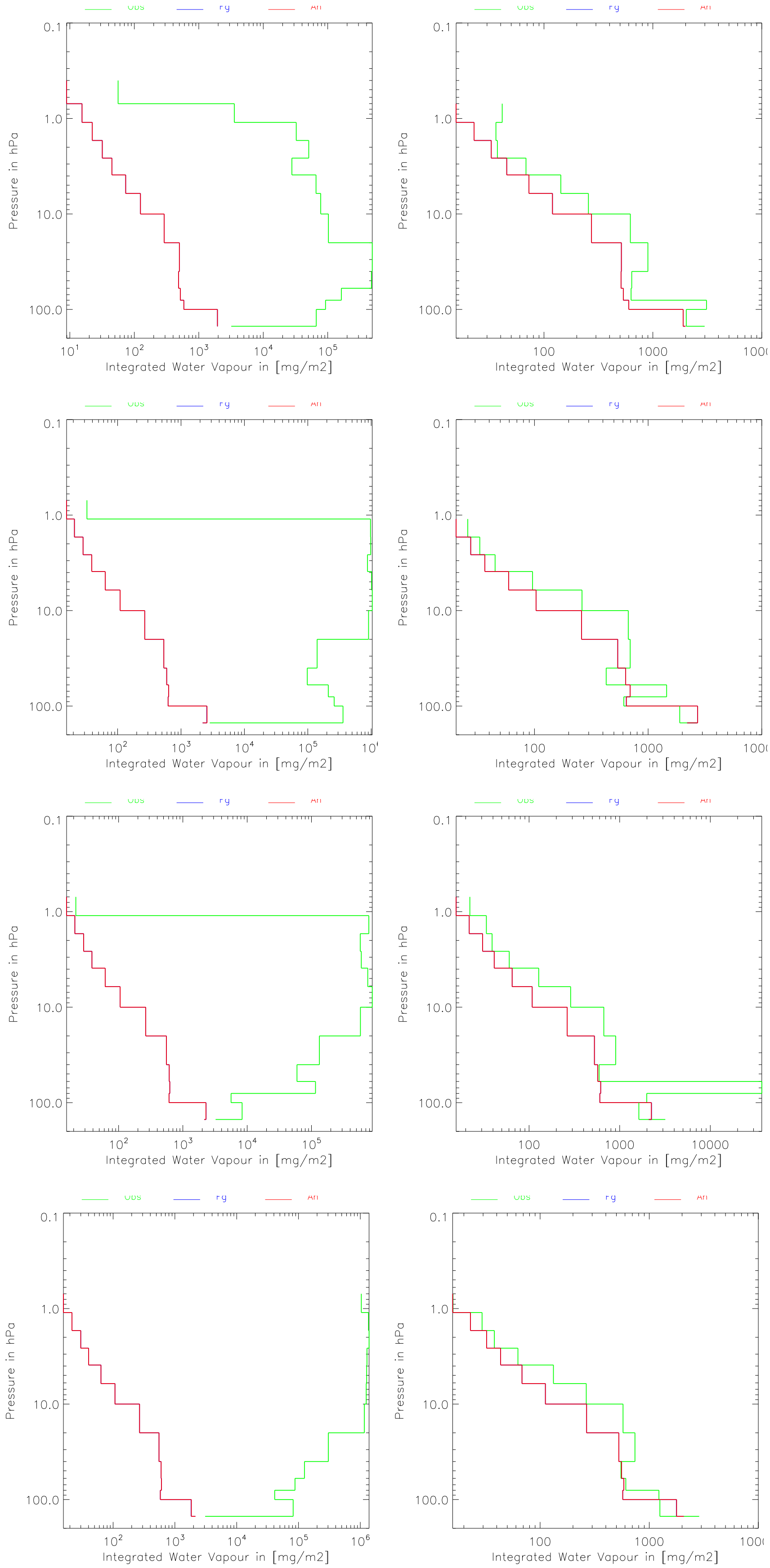


Figure 25: Like in figure 19, but for the water vapour. Data values are in mg/m^2.

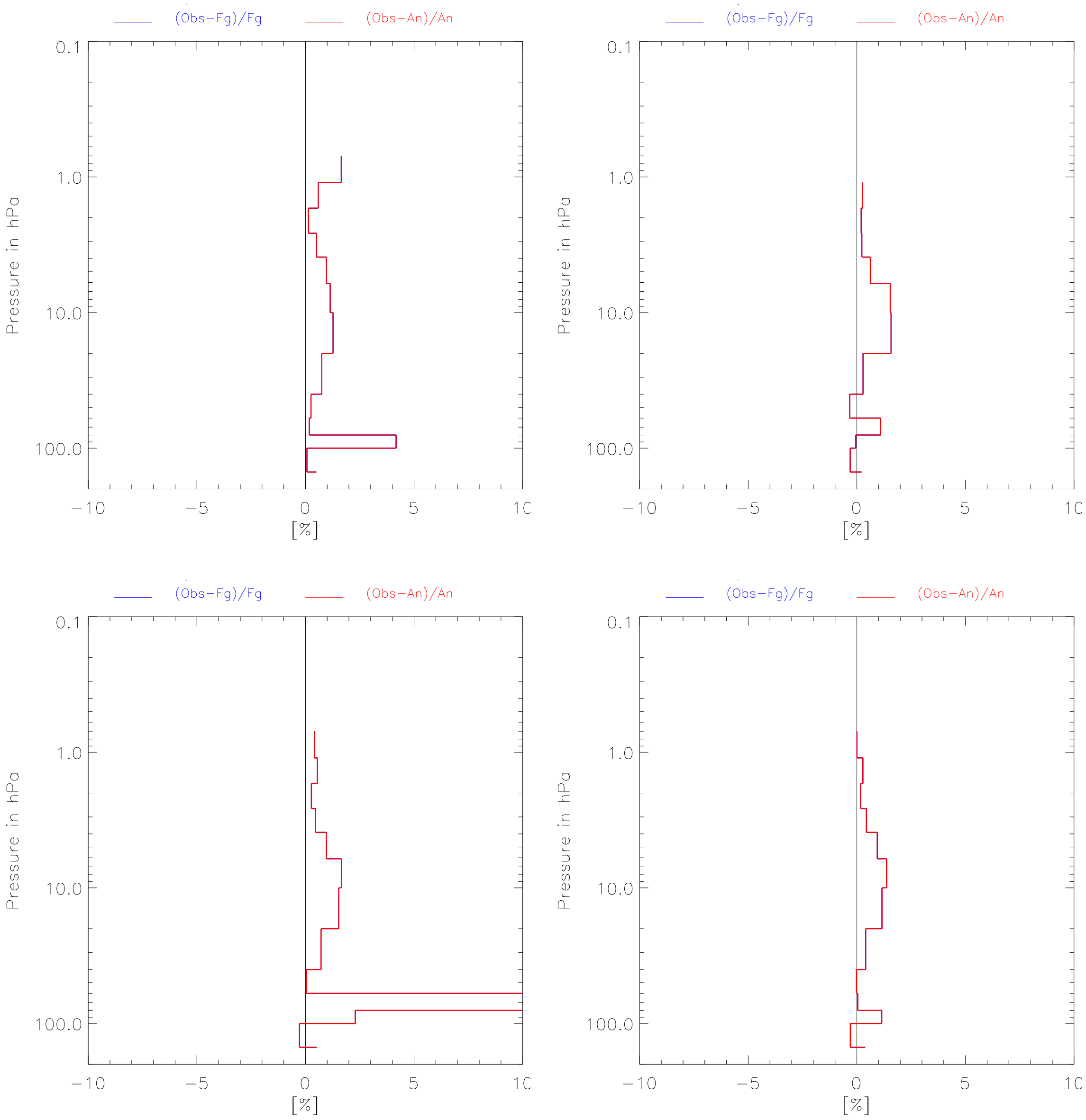


Figure 26: Comparisons between the global mean relative water vapour first-guess (blue) and analysis (red) departures obtained from the new dataset. The averaging periods are (clockwise from top left) for September 2007, October 2007, November 2007, and December 2007. Data values are in %.

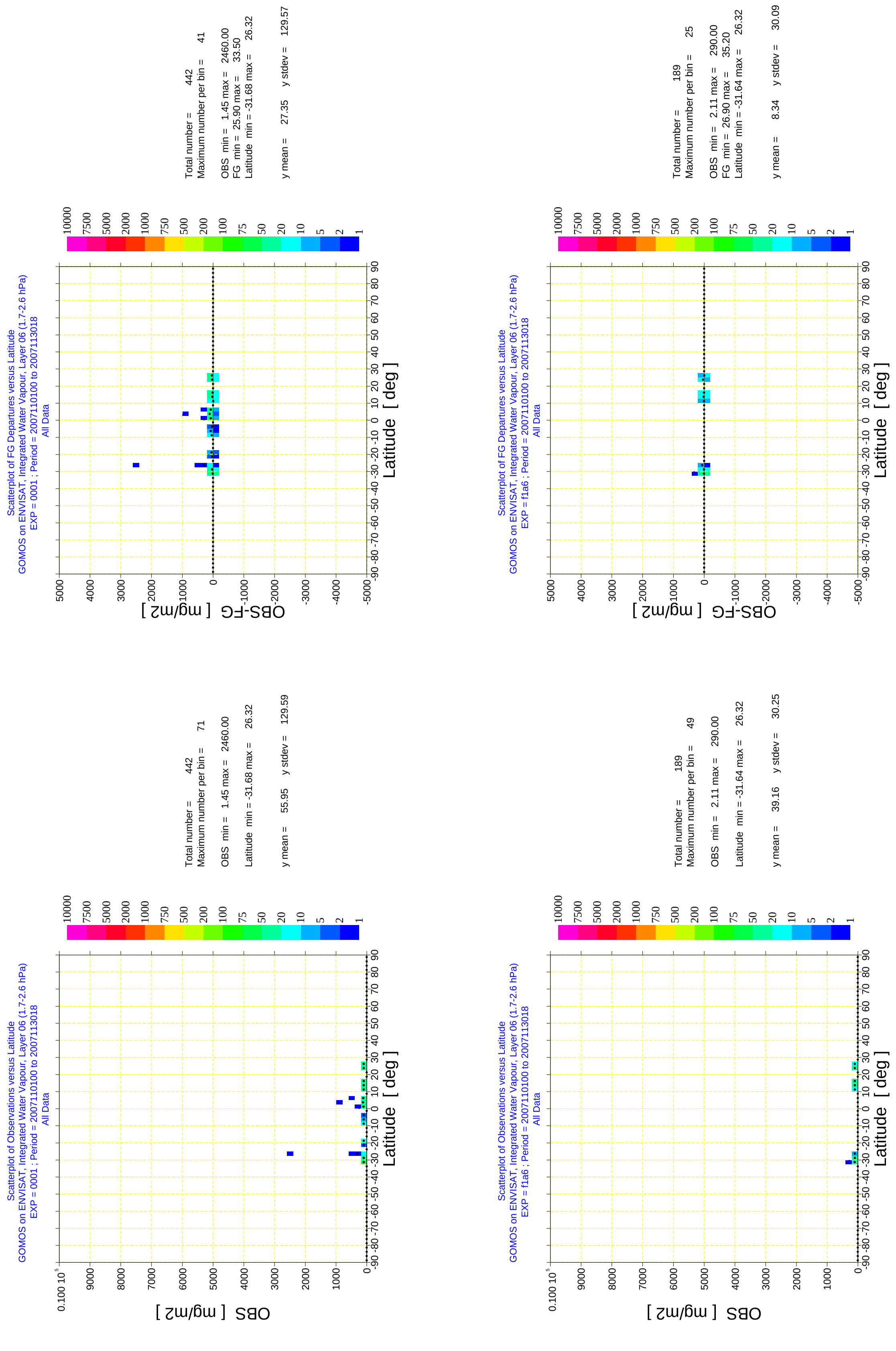


Figure 27: Like in figure 21, but for WV at layer 6 (1.7-2.6 hPa).

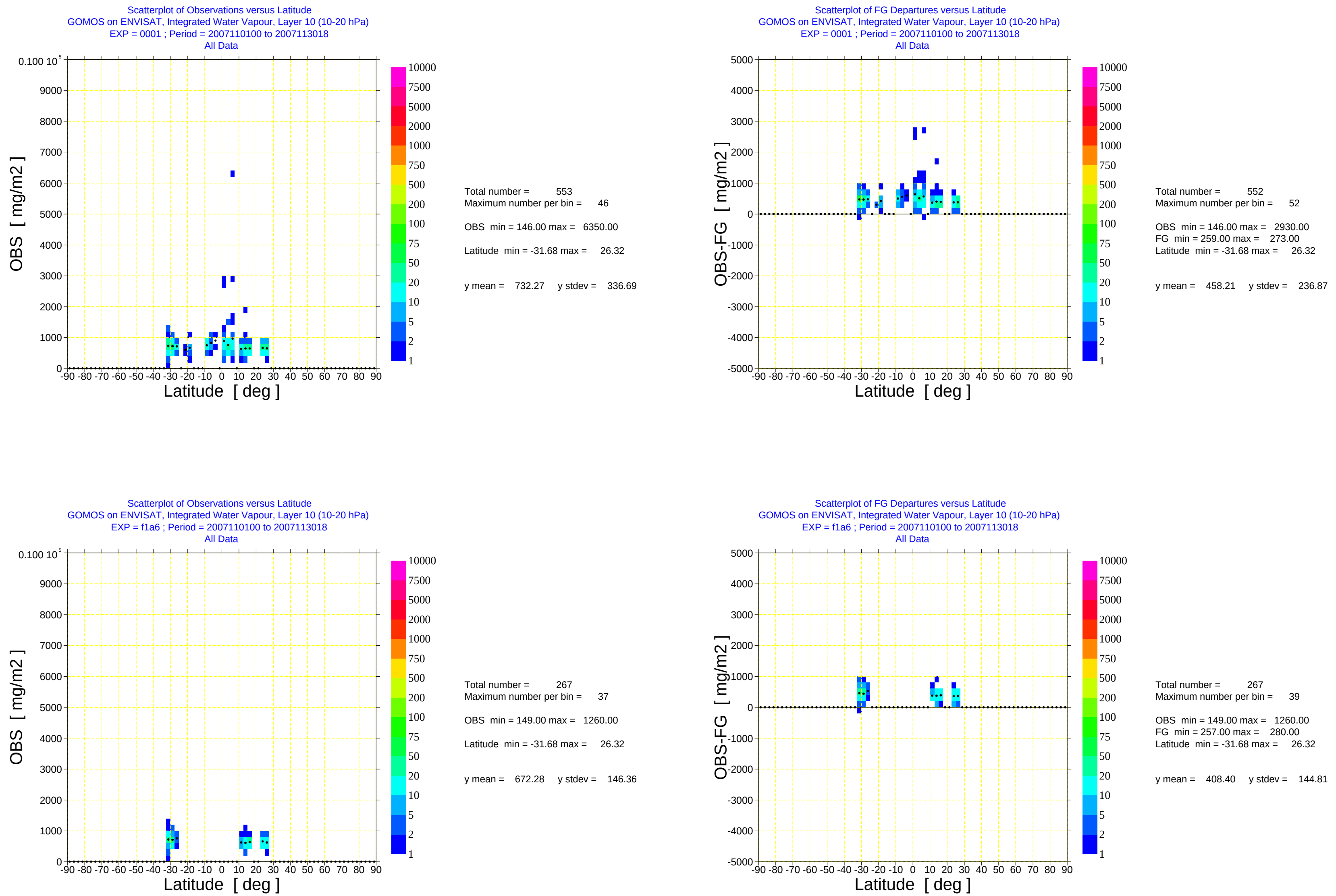


Figure 28: Like in figure 22, but for WV.

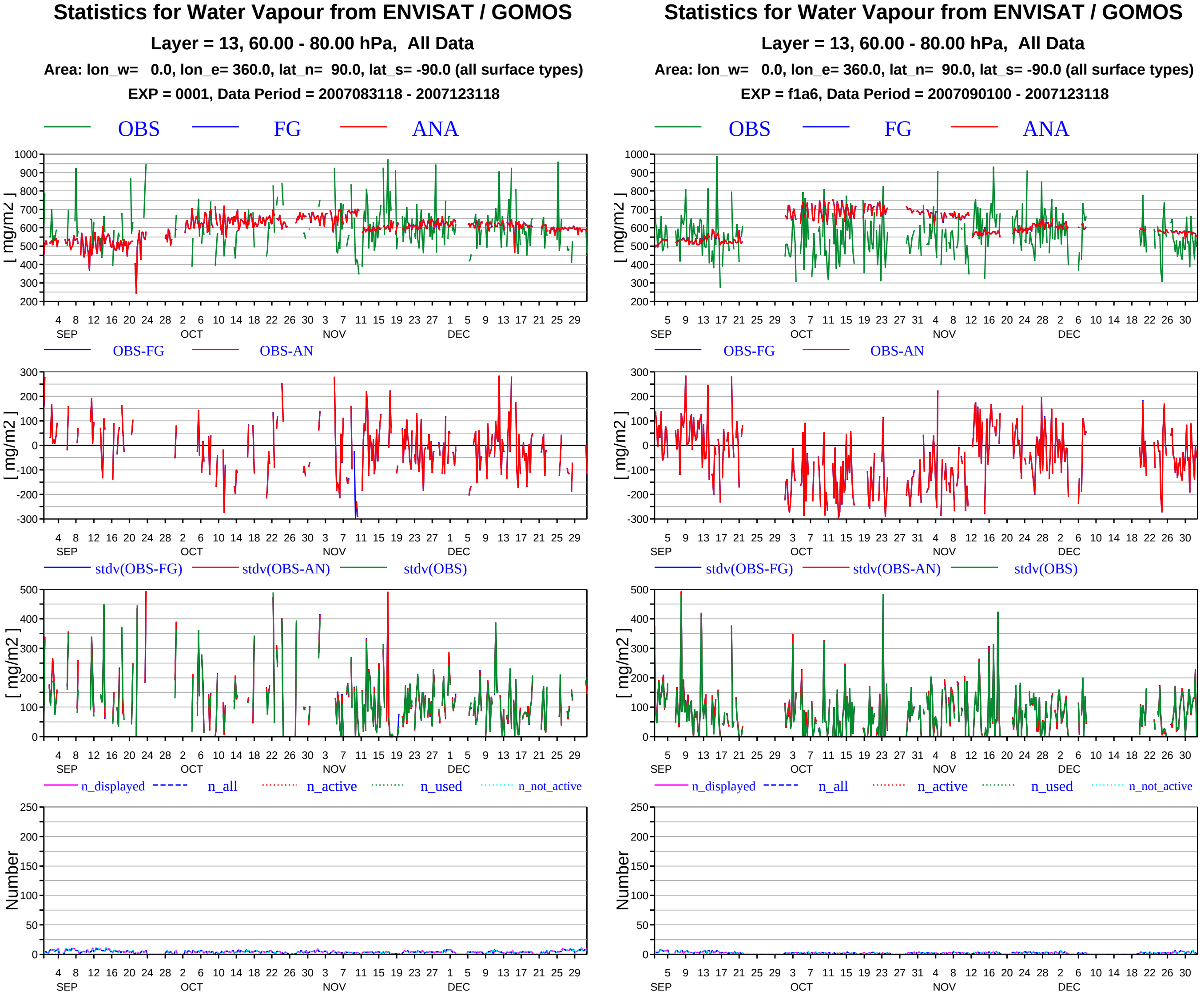


Figure 29: Like in figure 24, but for the WV at layer 13 (60-80 hPa).

5 Monitoring of MIPAS data

Owing to instrument problems, NRT Level 2 MIPAS data (MIP_NLE_2P) have not been available since 27 March 2004, so that no monitoring activity of these observations could be performed during 2008. Results from the monitoring statistics covering the period October 2003 - March 2004 were presented by Dethof (2004).

The planned assessment of the MIPAS L2 data retrieved from the low spectral resolution data sampled during the period October-December 2007 will be performed as soon as the data will become available. This depends upon the operational implementation of the new MIPAS processor, which is now planned for the end of March 2009.

In addition, research activity to assess the impact of assimilating low spectral resolution MIPAS level 1 radiances on the ECMWF ozone analyses started during 2008. A similar test was already carried out within the Assimilation of Envisat data (ASSET) project (Bormann and Thépaut, 2006; Bormann et al., 2006), using the full spectral resolution radiances. Before any assimilation experiment could be performed, some preparation work was needed. In particular, because of the different spectral resolution of the current radiance data compared with that of the dataset assimilated in ASSET, a new set of coefficients used in the regression model, which parameterizes the transmittance in the radiative transfer model, RTMIPAS (Bormann et al., 2005), had to be calculated. Once this new set of coefficients were calculated, the performance of RTMIPAS was checked, and compared with that obtained with the full spectral resolution data. The next step concerns with the actual selection of a suitable subset of MIPAS channels to be used in the assimilation experiments. The results and findings on the activity performed as preparation to the MIPAS level 1 radiance assimilation will be produced separately.

6 Conclusions

Under ESA contract 21519/08/I-OL (Technical support for global validation of Envisat data products) NRT GOMOS (GOM_RR__2P) products were monitored at ECMWF using the operational assimilation system. Because of instrumental problems which caused the unavailability of the NRT MIPAS (MIP_NLE_2P) product, no monitoring could be performed of these data since 27 March 2004. In addition, the monitoring of the NRT SCIAMACHY (SCI_RV__2P) product could not be performed after May 2006 also due to data unavailability.

The NRT GOMOS products (GOM_RR__2P) were available during the whole 2008, with only a few short periods of unavailability. We also acknowledge that after a model cycle change at ECMWF in June 2008, the monitoring of the temperature product could not be performed for the period between 6 and 21 June. No impact was found in the monitoring of the other products.

Upon the data availability, an indication of the timeliness of the ENVISAT products during 2008 was provided. The timeliness of the TOSOMI products as downloaded by KNMI was just under 81% as annual average in 2008. As far as GOMOS products are concerned, about 96.4% of the data were received in time for the delayed-cut-off analyses during 2008.

The quality of the GOMOS temperature profiles was stable during 2008, and consistent with that reported by Dragani (2008). On average, the GOMOS temperature departures are less than -1% (-2 K) in most of the stratosphere and slightly larger in the mesosphere (up to -4%, about -8K between 0.2 and 0.4hPa).

As far as the NRT GOMOS ozone profiles are concerned, the global mean annual mean first-guess and analysis departures are within -5 and +20% in most of the stratosphere (for pressure values smaller than 40hPa), but larger departures were found on average in the lower stratosphere (for pressure values larger than 40hPa), and in the mesosphere. The standard deviations of the departures were found larger than 50% in most vertical layers. When averaging over latitudinal bands, the level of agreement just discussed is usually confirmed. The agreement between the GOMOS ozone observations and their model equivalent is better than the GOMOS ozone one standard deviation limit at all vertical levels and latitudinal bands. The largest differences are found in the lower stratosphere, typically for pressure values larger than 40 hPa, and in the upper mesosphere where the first-guess and analysis departures can be larger than 20%. The first-guess and analysis departure standard deviations are larger than 15% in the lower stratosphere and larger than 50% in the upper stratosphere and mesosphere.

The quality of the water vapour data was generally poor during 2008. The monitoring statistics for 2008 showed the GOMOS water vapour values were from one to four orders of magnitude larger than those given by the model at all stratospheric levels and latitudinal bands. The largest differences were found in the upper stratosphere, where not only did the GOMOS observations exhibit values of four order of magnitudes larger than their model equivalent on average, they also were larger than the mean GOMOS tropospheric observation. It should be noted that these data were selected from the whole set of measurements to be obtained from observations sampled in full dark illumination condition (changes in the BUFR converter were implemented in May 2007 as suggested by the GOMOS QWG).

The poor quality of the water vapour after May 2007 suggested that the filter implemented in the BUFR converter was not good enough to filter out all the bright, twilight and straylight data and that some poor quality observations could still be retained in the monitored dataset. Using the star identification, the GOMOS QWG prepared a new dataset of GOMOS water vapour and ozone data for the period between September and December 2007. These data were ingested in the ECMWF operational system and monitored. The monitoring statistics showed that the number of observations from the nine brightest stars that provided the highest quality data was strongly reduced with respect to the already filtered dataset. It was estimated that only 15% of the data actually fulfilled the condition of being sampled in full dark illumination condition. However, the quality of the new filtered dataset seem to be much improved for both ozone and water vapour. In particular, the ozone monitoring statistics show less scatter than the operational one during the whole period under study, and a higher level of agreement in particular in the mesosphere. As far as the water vapour is concerned, although both the operational and the new datasets show higher water vapour values than their model equivalent, the new dataset compares much better than the operational one with the ECMWF water vapour first-guess and analyses. Like for ozone, also the new water vapour data show less scatter than the operational GOMOS dataset. It is adviced the GOMOS data to be selected at the source according to the star identification number as done for the test dataset used in this study.

7 Acknowledgements

Information to calculate the statistics discussed in section 2 was provided by Susan Madry (ECMWF). The NRT OMI data and the NRT GOME2 data were provided by NASA and EUMETSAT, respectively.

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