

MONITORING OF SCIAMACHY TOTAL COLUMN OZONE USING THE DAO OZONE DATA ASSIMILATION SYSTEM

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ABSTRACT

The total column ozone data from SCIAMACHY were monitored in the ozone data assimilation system at NASA's Data Assimilation office (DAO). The ozone data from NOAA-16 Solar Backscatter UltraViolet/2 (SBUV/2) instrument are assimilated in the DAO's system. The monitoring consists of computing the differences between SCIAMACHY observations and the ozone system forecast, i.e. observed-minus-forecast (O-F) residuals. The O-F residuals are then analyzed using simple statistical methods. Two monitoring experiments were performed for SCIAMACHY data for the period from October 25 to December 1, 2002. In the first experiment no quality control other than the quality flag provided with the data was used. In the second experiment a simple range check (total column ozone values must be greater than 100 and less than 1000 Dobson units) was used to screen the data before monitoring. In both experiments large O-F residuals were concentrated in the northern and southern high latitudes at what appear to be high solar zenith angles near the terminator. In the experiment with the range check the zonal mean of SCIAMACHY observations is 20 to 30 Dobson units lower than that of the DAO forecast throughout the Tropics and mid-latitudes. At high latitudes where the magnitude of the O-F residuals is particularly large, however, the SCIAMACHY total ozone is higher than the DAO forecast.

1. INTRODUCTION

Since year 1999 the Data Assimilation Office (DAO) at NASA Goddard has operationally produced analyzed ozone fields based on the assimilation of Total Ozone Mapping Spectrometer (TOMS) and/or Solar Backscatter UltraViolet/2 (SBUV/2) data. Aside from providing near real time global maps of ozone, the analyzed fields are used for monitoring of satellite instruments. Currently, the data assimilation system is configured to actively assimilate SBUV/2 profile and total column measurements while monitoring or passively assimilating SCIAMACHY data.

Fig. 1 is a schematic overview of the ozone data assimilation system at the DAO. An initial ozone field is evolved using a parameterized chemistry and transport model (CTM) with the parameterized chemistry based on climatology provided by the Free University of Berlin [1] and production and loss rates derived from a full CTM (A. Douglass, personal communication). Using the DAO's operationally produced fv-DAS (GEOS-4) winds, the ozone is advected by a flux form semi-Lagrangian scheme at a discretization of 2×2.5 degrees and 29 hybrid pressure levels. The time step for the advection is 15 minutes, and the output is a short-term forecast. The forecast is combined with forecast error models, observation error models, and the ozone data in a statistical analysis scheme. The statistical analysis produces analysis increments that are added to the forecast yielding an analyzed ozone field. The analyzed field is then fed back into the CTM, and the process repeats [2 and references therein].

In addition to producing the analyzed field, the assimilation system also generates analysis increments and O-F residuals. The O-F residuals are used to monitor observation and forecast errors, and the validity of error covariance models. The analyzed fields are compared for previous assimilation periods with Halogen Occultation Experiment (HALOE), and ozone sondes to monitor the accuracy of the system.

The system currently has the capability to actively assimilate any combination of SBUV/2, TOMS, and Microwave Limb Sounder (MLS) data. In addition, the system monitors (or passively assimilates) SCIAMACHY data. In monitoring, data is fed into the statistical analysis, O-F residuals are computed, but these residuals are not allowed to impact the analysis increments. The system is currently set up to monitor SCIAMACHY data, and the software for monitoring and/or actively assimilating SCIAMACHY and MIPAS data is under development.

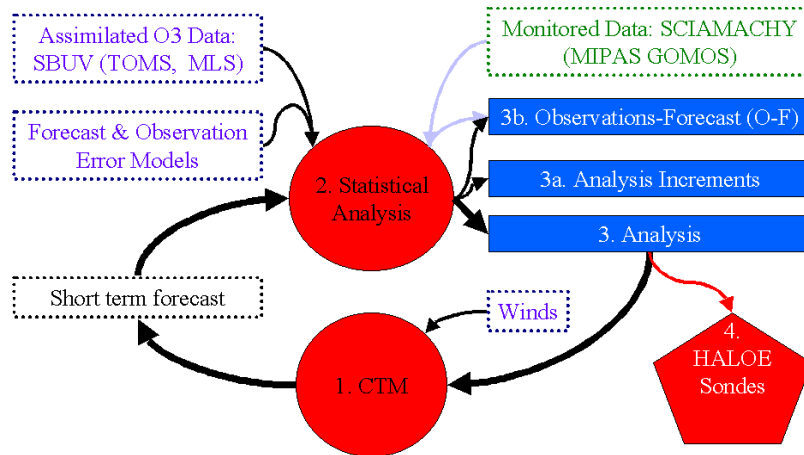


Fig. 1. Schematic overview of the assimilation system at the DAO. 1. A chemistry transport model (CTM) advects the ozone field producing a short term forecast which is used in the statistical analysis (2). The statistical analysis combines observation error models, forecast error models and SBUV/2 ozone data to produce analyzed ozone fields (3). The fields are compared to HALOE and ozone sondes. O–F residuals are generated for SBUV/2 and SCIAMACHY data.

2. MONITORING OF SCIAMACHY TOTAL COLUMN OZONE

Two assimilation experiments were run to monitor SCIAMACHY level 2 data from October 25 to December 1, 2002. The data were extracted from the PDS format (RV_2 files) and converted to a format needed in the ozone assimilation system using the PDS2Ascii tool available with Enviroview 2.0.7. The dsr_time from the O3_VERTICAL_COLUMN field was matched to the dsr_time from the GEOLOCATION field. Integration time was not considered in this matching. Due to numerous changes in the level 2 processing algorithm, the resulting improper assignment of values to the four corner coordinates over this time period, as well as the coarseness of the assimilation grid relative to the foot print of the SCIAMACHY instrument, the fourth corner coordinate at the initial dsr_time was used as a center coordinate. The data in both experiments were screened with at least the quality flag provided in the RV_2 files.

2.1 Monitoring Using All Data

Fig. 2 is a time series plot that illustrates the effects of having no quality control other than that provided by the quality flag present in the RV_2 files. The daily global Root Mean Square (RMS) of the O–F residuals that were obtained without additional quality control are shown by red dots. These values are typically above 200 Dobson units and occasionally approach 3000 Dobson units. In contrast, the SBUV/2 total column RMS of O–F residuals are typically around 15 Dobson units. This implies that some SCIAMACHY ozone values are well outside the expected range.

Daily RMS of total column O-F residuals

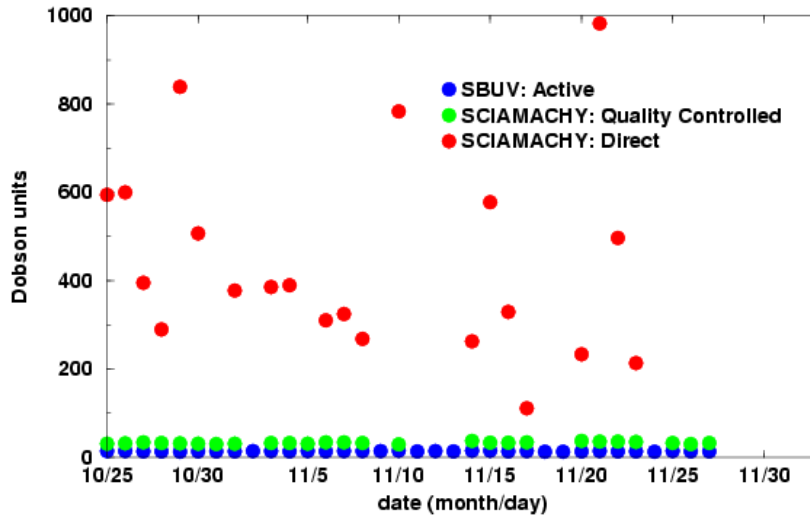


Fig. 2. Daily global RMS of O-F residuals for assimilation experiments using SBUV actively (blue) and either SCIAMACHY data with no external quality control (red), or SCIAMACHY with simple quality control (green, see section 2.2).

The residuals in fig. 2 are globally averaged. There is, however, a latitudinal dependence of these high O-F residuals. In fig. 3, the O-F residuals are grouped by latitude bands and plotted in time series. The highest O-F residuals are indeed concentrated at northern and southern high latitudes apparently at high solar zenith angles near the terminator.

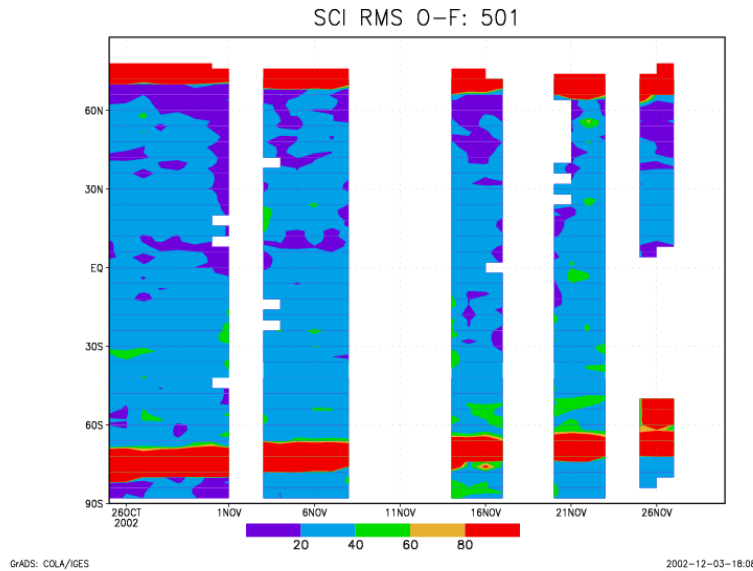


Fig. 3. Zonal average time series of the RMS of O-F residuals grouped into 2 degree bins. Most values range between 0 and 60 Dobson units. Values above this are concentrated in the northern and southern high latitudes.

Fig. 4. shows that the daily regional mean of the reported errors in observations (given in percent) exhibit latitudinal dependence similar to that seen in the high RMS of O-F residuals (the relatively large and relatively small errors are concentrated in the southern and northern high latitudes). In fact, most (>99%) of the large RMS values correspond to a reported error larger than 1.2%, which is relatively large compared to most reported errors, or equal to 0.0%. This implies that error values greater than 1.2% could be used as a quality screen.

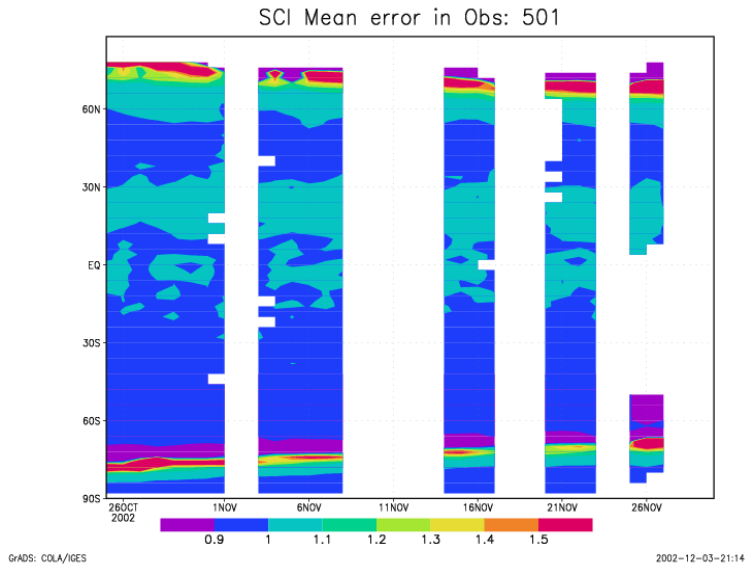


Fig. 4. Zonal averaged time series of the mean error as reported in the RV_2 data files grouped into 2 degree bins. Most values range between 0.9 and 1.2% error. Values below that are most often zero. All values outside of this range are concentrated in the northern and southern high latitudes, and are often reported as 0%.

The reported errors outside of the 0.9 – 1.2% range are constrained in longitude as well as latitude. Fig. 5. shows that the on a given day, the relatively large or relatively small values of the regional mean of the reported error in observations is tightly concentrated in space at what appear to be high solar zenith angles near the terminator. Similar plots for the RMS of O–F residuals show that most (>99%) of the large RMS values correspond to the regions where reported errors are larger than 1.2% or equal to 0.0%.

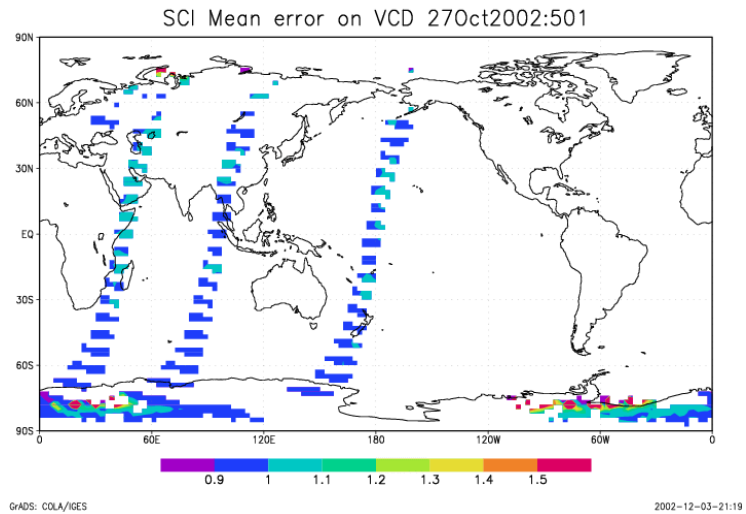


Fig. 5. Map view of the mean reported error from the RV_2 files. Values are averaged within 2x2 degree bins. Relatively high and low error values are tightly clustered in space at what appear to be high solar zenith angles near the terminator.

2.2 Monitoring Using Quality Controlled Data

When the SCIAMACHY data to be monitored are screened with a range check (total column values must be between 100 and 1000 Dobson units), the daily global RMS of the O–F residuals decrease dramatically. Fig. 6. is a time series plot of the daily global RMS of O–F residuals. The daily global RMS between quality controlled SCIAMACHY total ozone and the forecast is between 30 and 40 Dobson units. These residuals are represented by green dots in fig. 6. Blue dots correspond to residuals from the active assimilation of SBUV/2 total column observations. These values are typically near 15 Dobson units.

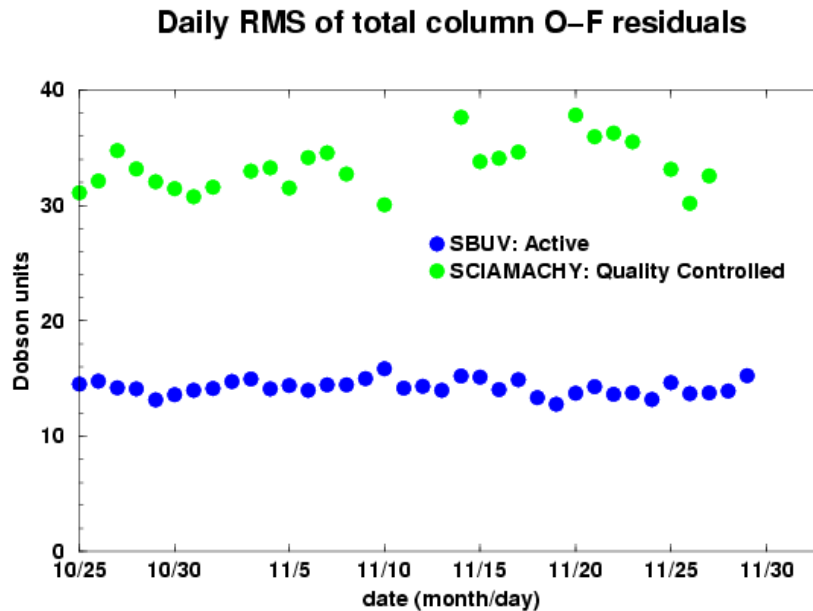


Fig. 6. Daily global RMS of O–F residuals for the experiment monitoring SCIAMACHY data with an external quality control (green), and actively assimilating SBUV total column ozone (blue). The quality control consists of a range check: SCIAMACHY total column values must be greater than 100 Dobson units, or less than 1000 Dobson units.

Even with the quality control applied, the latitudinal dependence of the high O–F residuals remains. As was the case with the experiment without the quality control, the biggest O–F residuals are still concentrated at northern and southern high latitudes apparently at high solar zenith angles. The magnitude of the zonal RMS of the O–F's are smaller for quality controlled data (fig. 7) than for all data (fig. 3).

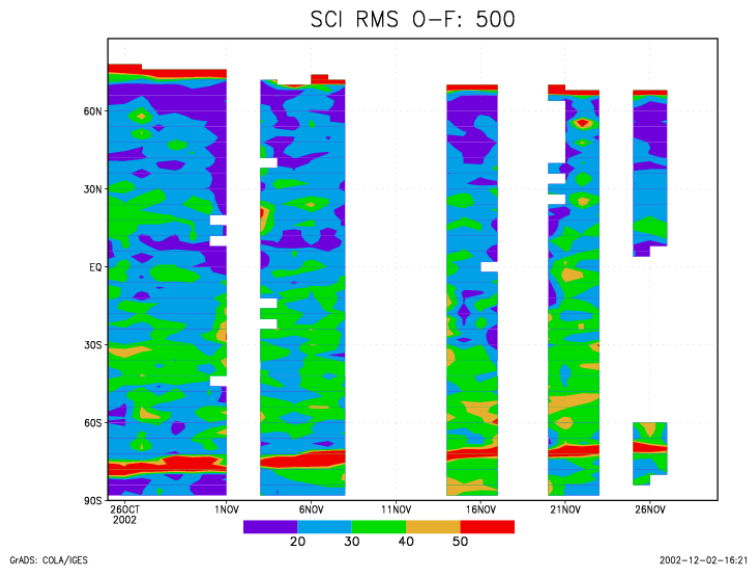


Fig. 7. Zonal average time series of the RMS of O–F residuals grouped into 2 degree latitude bins after quality control is applied. Values typically range between 0 and 60 Dobson units. Residuals larger than this are mostly concentrated in the northern and southern high latitudes.

With the observations failing the range check and producing the largest O–F residuals removed, biases between the forecast and the observations can be better examined. Fig. 8, a time series of the zonal mean of O–F residuals (in Dobson units) shows that there are indeed biases in the remaining observations. The SCIAMACHY total column ozone is lower than forecasted total ozone column by 25, 30, and 35 Dobson units in the northern mid latitudes, tropics, and southern mid latitudes, respectively. This implies that the magnitude of O–Fs increases towards the southern midlatitudes. In addition, positive O–F’s are mostly concentrated at northern high latitudes.

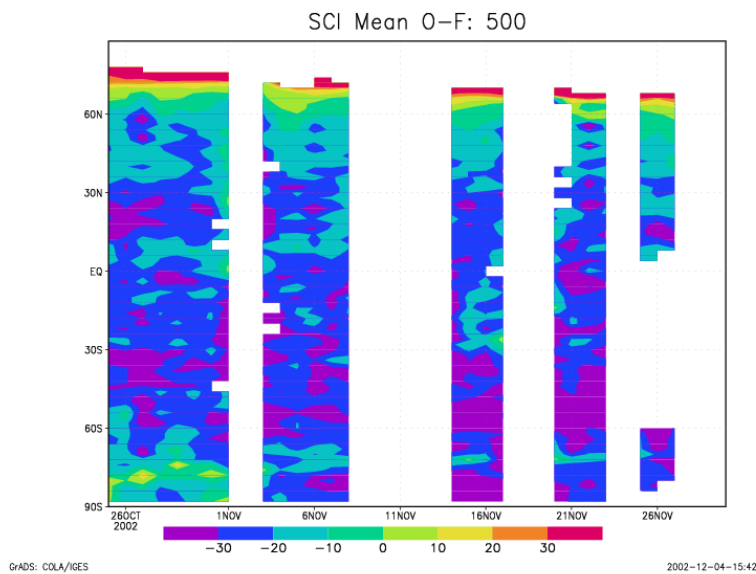


Fig 8. Time series of the zonal mean of O–F residuals grouped into 2 degree latitude bins after quality control is applied. Most values imply that the forecasts are overestimating the observations by 20 to 30 Dobson units. The forecast is underestimating the observations, however, at northern high latitudes.

Map views of the mean of O–F residuals, however, indicate that the patterns of biases mentioned above are more tightly constrained in space. Fig. 9 shows a map of the regional mean of O–F residuals and further highlights the spatial pattern of these biases. Large positive O–F residuals are tightly clustered. Most (>99%) of these large residuals correspond to reported errors larger than 1.2%, and again are likely associated with the high solar zenith angles. In other regions, most of the mean O–F residuals are negative, implying that the SCIAMACHY observations are lower than the DAO’s forecast by between 20 and 30 Dobson units.

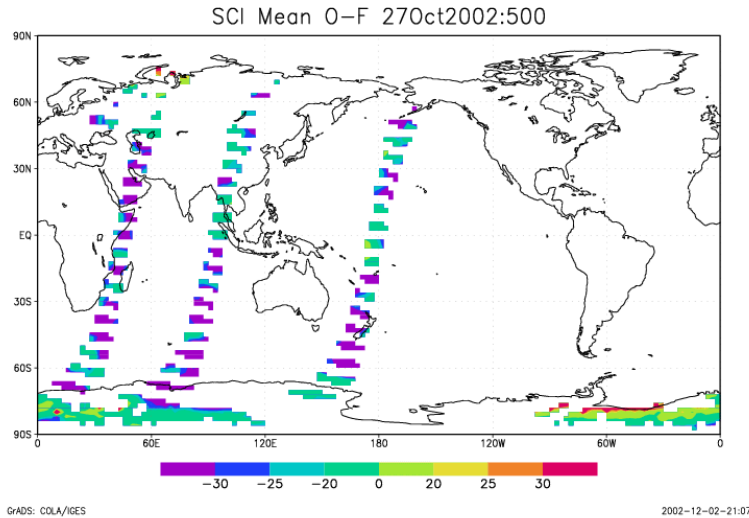


Fig.9. A map view of the mean of O–F residuals grouped into 2x2 degree bins. Relatively large positive values are tightly clustered in space apparently near the terminator. Most other values imply the forecasts are overestimating the observations by 20 to 30 Dobson units.

3. SUMMARY

Without the application of a range check, the monitoring of SCIAMACHY total column ozone values shows very large RMS of O–F residuals, typically exceeding 200 Dobson units in global daily average. Application of a range check, which discards data lower than 100 or higher than 1000 Dobson units, reduces the global RMS of O–F residuals to 30–35 Dobson units. With or without the quality control, the largest O–F residuals are tightly concentrated in northern and southern high latitudes at what appear to be high solar zenith angles, but the solar zenith angle information is not yet provided in the data. These areas also have relatively large reported errors (greater than 1.2%), and their forecasts generally underestimate the observations. Outside of these areas, the forecasts typically overestimate the observations by 20–30 Dobson units.

4. REFERENCES

1. Langematz U., An estimate of the impact of observed ozone losses on stratospheric temperature, *Geophysical Research Letters*, Vol. 27, 2077–2080, 2000.
2. Stajner I., Riishojgaard L. P., and Rood R. B., The GEOS ozone data assimilation system: specification of error statistics, *Q. J. R. Meteorol.*, Vol. 127, 1069–1094, 2001.