Comment from Robert Damadeo regarding the paper in discussion: Nedoluha, G. E., Siskind, D. E., Lambert, A., and Boone, C.: The decrease in mid-stratospheric tropical ozone since 1991, Atmos. Chem. Phys. Discuss., 15, 453-480, doi:10.5194/acpd-15-453-2015, 2015.

The authors draw a correlation between reactive nitrogen, N_2O, and ozone in the tropical middle stratosphere and discuss the resulting trends in this region using data from HALOE and MLS. The authors make use of a regression applied to monthly median data from both HALOE and MLS separately. This regression model uses annual (2), semiannual (2?), QBO (2), solar (1), and linear trend (1) terms to derive long-term trends in ozone as shown in Figs. 2 and 3 of the paper. After reading through the methodology and analysis used by the authors, I have some concerns regarding the validity of the existence of a long-term trend in ozone in the tropical middle stratosphere.

The concept of applying a multiple linear regression model to a (or multiple) long-term ozone dataset (or datasets) has been done many times as pointed out by the authors. This methodology is well documented and the subsequent uncertainty analysis is also reasonably documented amongst various papers. However, the necessary description of the required uncertainty analysis is absent from this work. Nowhere in this paper are the uncertainties in the resulting trends discussed. These uncertainties should come directly from the regression analysis (uncertainties in the regression coefficients). Furthermore, a proper autocorrelation correction needs to be incorporated in order to ensure the subsequent uncertainties in the coefficients are not underestimated. The resulting trends cannot be considered definitive without the knowledge of a corresponding level of significance (2σ is generally appropriate).

As the authors point out, this kind of analysis has been done many times before, most often with SAGE II data. These studies referenced in the paper show varying trends in the tropical middle stratosphere with varying levels of significance. However, it has been shown recently in Damadeo et al. (2014) that the non-uniform sampling of an instrument (specifically SAGE II but applicable to other occultation instruments such as HALOE and ACE) can induce biases in derived trends if not handled properly. Even something as simple as taking a monthly mean (or median) can create an artificial trend due to the fact that the sampling does not always fall at the center of the given month, but is typically treated as such in the regression. For example, the tropical sampling of HALOE moves earlier each subsequent year due to precession of the orbit (see Fig. 1 of this comment). This will induce an apparent negative trend for months before the seasonal ozone peak and an apparent positive trend for months after it. Similarly, the act of taking monthly means/medians or even regressing a seasonal cycle in order to deseasonalize data can create biases depending upon how other terms (e.g., the QBO) interact with the seasonal cycle in phase and magnitude. While the authors do not regress to deseasonalized data, Fig. 1 of the paper can be influenced by this effect.

While many previous works referenced by the authors show a negative trend in tropical mid-stratospheric ozone in the late 1990s, the work of Damadeo et al (2014) does not, in part due to the proper treatment of non-uniform sampling in the dataset. An aspect of that work was repeated, only many of the terms previously used in the model were turned off in order to try to duplicate the work of Nedoluha et al. (2015). Unfortunately, no combination of model terms yielded a negative trend in the tropical middle stratosphere in the late 1990s. In a further effort to replicate the work at hand, only data after the start of 1992 were used in the regression and instead of multiple trend terms, a single linear trend was used. Another of the major differences between the work of Damadeo et al. (2014) and other referenced works is the creation and inclusion of a volcanic proxy term (valid over the lifetime of the SAGE II mission). If a simplified model comparable to that of the authors is applied to data after the start of 1992, a statistically significant negative linear trend in ozone is seen in the tropical middle stratosphere (Fig. 2 of this comment). However, if the volcanic proxy is then included in the regression (Fig. 3 of this comment), the linear trend becomes statistically insignificant over this time period and is subsequently (and automatically) removed by the algorithm performing this work. The derived linear trend in this particular case is actually insignificant even at the 1σ level. As such, it would seem that no statistically significant trend is present in the HALOE data. Instead, any apparent trend is likely the result of the influence of the Mount Pinatubo eruption and the fact that the HALOE data used begins right near the peak of interfering aerosols from the eruption.

While the authors of Damadeo et al. (2014) are working on expanding their technique to include other datasets (such as HALOE and MLS), this work is not yet ready. As such, a similar analysis cannot yet be applied to MLS data to validate or refute the existence of a trend in ozone in this region. However, given the reservations already stated in this comment, I do not believe the authors have demonstrated this either. Figure 1 of the paper is somewhat misleading. The design of the figure gives the impression of a negative trend in tropical mid-stratospheric ozone where one may not exist. While MLS data are not subject to the same sampling issues as SAGE II or HALOE, they are subject to the methodology applied. Figure 5 of the paper shows the monthly values of MLS ozone in the tropical middle stratosphere. It is not immediately obvious that a trend exists in this data; rather the data is dominated by the seasonal cycle and QBO. It appears that the amplitude of the QBO induced oscillation increases later in the dataset, which has lower troughs but peaks at a roughly constant level. However, the regression analysis applied in this paper starts in 2004 (near a QBO induced peak) and runs to mid-2013 (near a QBO trough), not mid-2014 when the QBO induced oscillation has reached a peak again. As such, if the QBO term used in the regression is not entirely representative of QBO induced oscillations, a negative trend would be derived that may not exist.

In conclusion, it is my opinion that the authors have not demonstrated that a statistically significant trend exists in tropical mid-stratospheric ozone between 1992 and 2014; rather the derived trends are a byproduct of endpoint anomalies. The authors should elaborate more on the applied technique and show levels of significance of their derived results. Furthermore, it seems apparent from the work shown here that while a decrease in ozone is apparent through the mid-1990s, it is the result of a perturbation caused by the Mount Pinatubo eruption and not by long-term changes in dynamics, which would have relaxed into the late 1990s.

Reference:

Damadeo, R. P., Zawodny, J. M., and Thomason, L. W.: Reevaluation of stratospheric ozone trends from SAGE II data using a simultaneous temporal and spatial analysis, Atmos. Chem. Phys., 14, 13455-13470, doi:10.5194/acp-14-13455-2014, 2014.

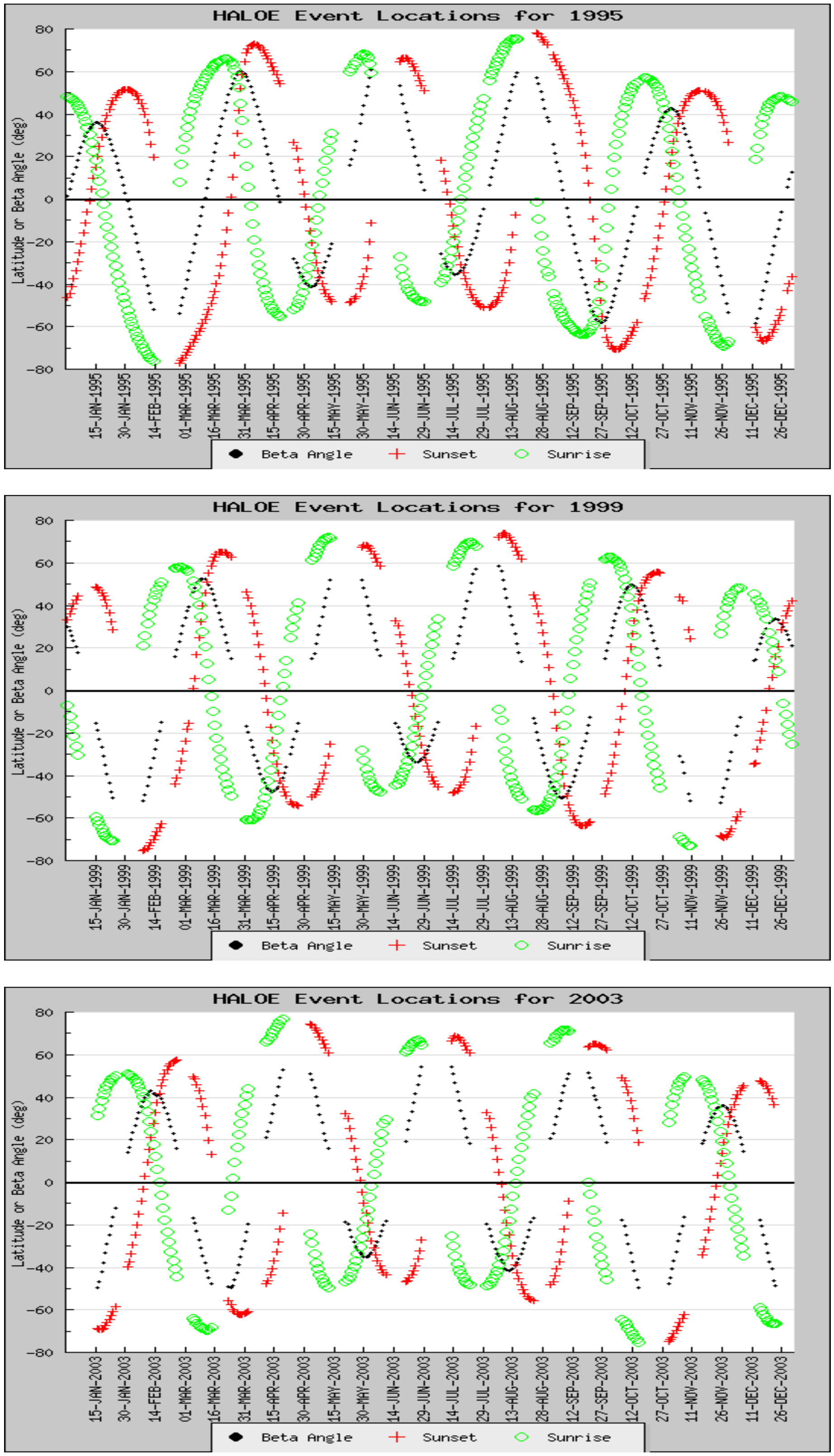

Figure 1: HALOE coverage maps for the years 1995, 1999, and 2003. (`http://haloe.gats-inc.com/coverage/index.php`)

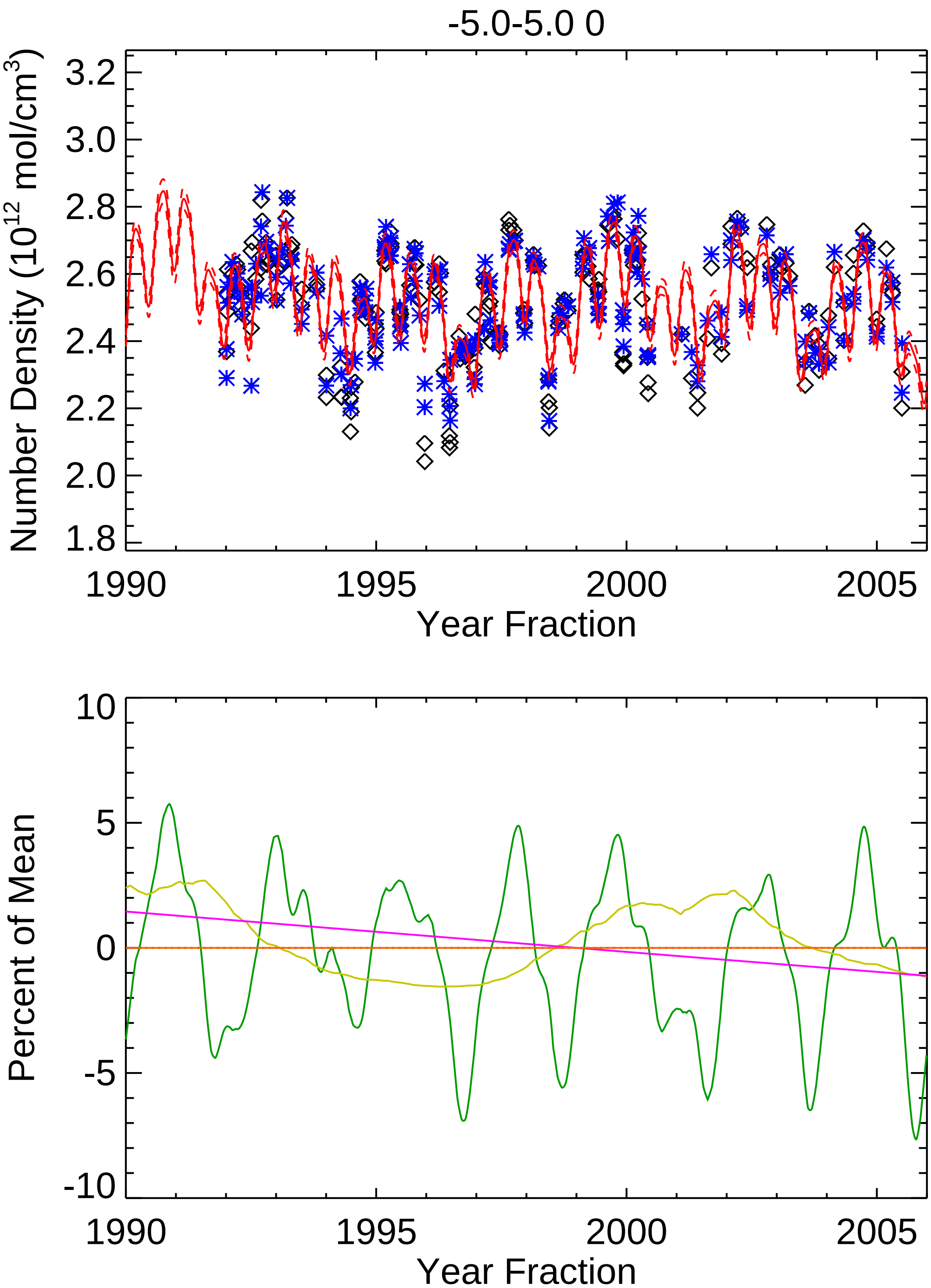

Figure 2: Results of the regression analysis. The top plot shows all daily means between 5 S and 5 N. The black diamonds represent the original data while the blue asterisks represent the data corrected for autocorrelation and diurnal variation. The red solid and dashed lines represent the associated fit and uncertainties at the Equator. The bottom plot shows the contribution of various terms as a percentage of the local mean. The QBO is shown in green, solar cycle in yellow, volcanic in orange, and linear trend in purple. The volcanic term is turned off for this regression.

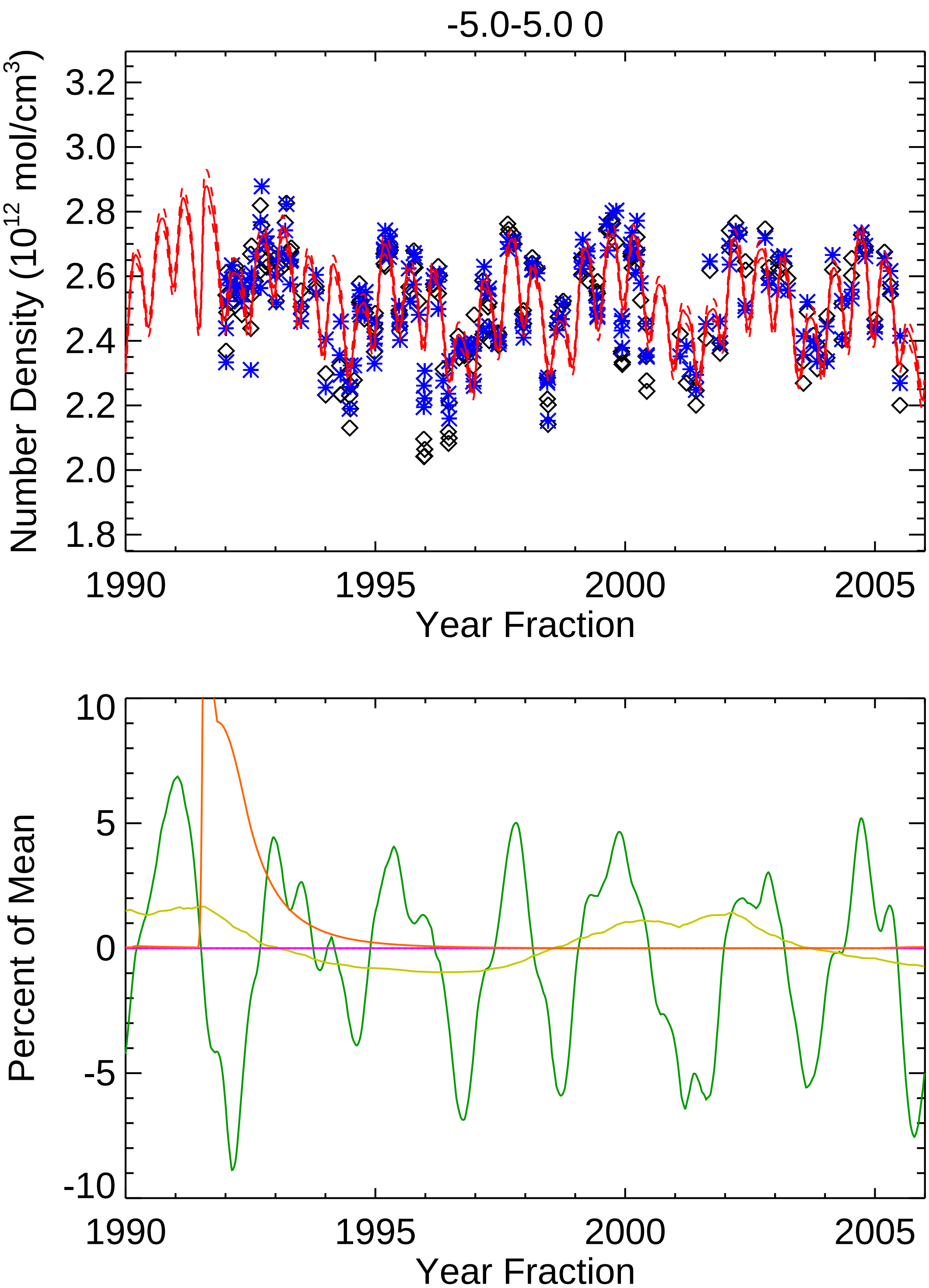

Figure 3: Results of the regression analysis. The top plot shows all daily means between 5 S and 5 N. The black diamonds represent the original data while the blue asterisks represent the data corrected for autocorrelation and diurnal variation. The red solid and dashed lines represent the associated fit and uncertainties at the Equator. The bottom plot shows the contribution of various terms as a percentage of the local mean. The QBO is shown in green, solar cycle in yellow, volcanic in orange, and linear trend in purple. The regression analysis automatically turns off any term not significant at the 2σ level.