Response to referee 2

Thanks, one again, for the extremely helpful comments

We use the total ozone data to determine the geographic location of the fronts by locating the position of the increase in the total ozone amount due to the decrease in the tropopause height associated with the fronts. Figure X (attached) shows a schematic of the total ozone values at the fronts, located at latitude of 30 and 60 degrees respectively, and compares the values for two instruments for three specific cases of a bias. Figure Xa shows the case when there is a constant bias between the two data sets, Figure Xb shows a case where there is a bias that is a function of latitude (or total ozone amount), and figure Xc shows a case where the total ozone value increases with latitude. The latter case is observed typically for the winter months indicating a drop in the tropopause height with latitude. The quantity that is retrieved from our analysis is the total ozone value at the center of the increase at the boundary. Although the value of the total ozone at the boundary can differ for each instrument, the geographic position of the boundary cannot. We use a contour program to delineate the frontal boundaries and, as long as the particular derived ozone boundary value for that particular instrument is used on that instrument's data set, the geographic position of the boundary should be independent of any observed bias in the total ozone data including a long-term trend.

It should also be noted that the TOVS_NOAA data set differs from the other data sets in two important ways. The day as defined in the TOVS_NOAA data goes from 0Z to 0Z, while for the other data sets it goes from dateline to dateline. In addition, the geographic locations of the TOVS_NOAA data are at the latitude/longitude grid points, and the dimensions for each day are [181,360]. For the other instruments the ozone values are the average within the box defined by the grid points and have the dimensions of [180,288] for TOMS and [180,360] for OMI and TOVS_NEURAL. The TOVS_NOAA data used in this analysis was first reformulated to match the other data sets. This did not involve correcting any bias in the original ozone data.

Figure 2 in the paper compares the derived values of total ozone that correspond to the boundaries of the fronts for the eleventh day of March, June, September, and December of 2006. The values for the TOVS_NOAA and OMI have been adjusted for each particular day for any bias. It should be stressed that in the analysis reported in this paper no bias is applied, each data set is evaluated separately. The agreement between the adjusted values from each instrument is excellent, and the differences shown in Figure 2 lead to a maximum error in the determination of the mean latitude of 0.2 degrees, which is less than the spatial resolution of the instruments. In general at least two instrument data sets can be used to derive the geographic boundary, the exception being between 1993 and 1996, when TOVS was the only data set available.

The monthly average used in the analysis is the mean value of the daily values for that month. As well as the mean we also determine the standard error of the mean which takes into account auto-correlation. These errors are then propagated through the regression analysis in determining the final error of the fit and the error in the individual indices. The same errors are also applied to the linear fit.

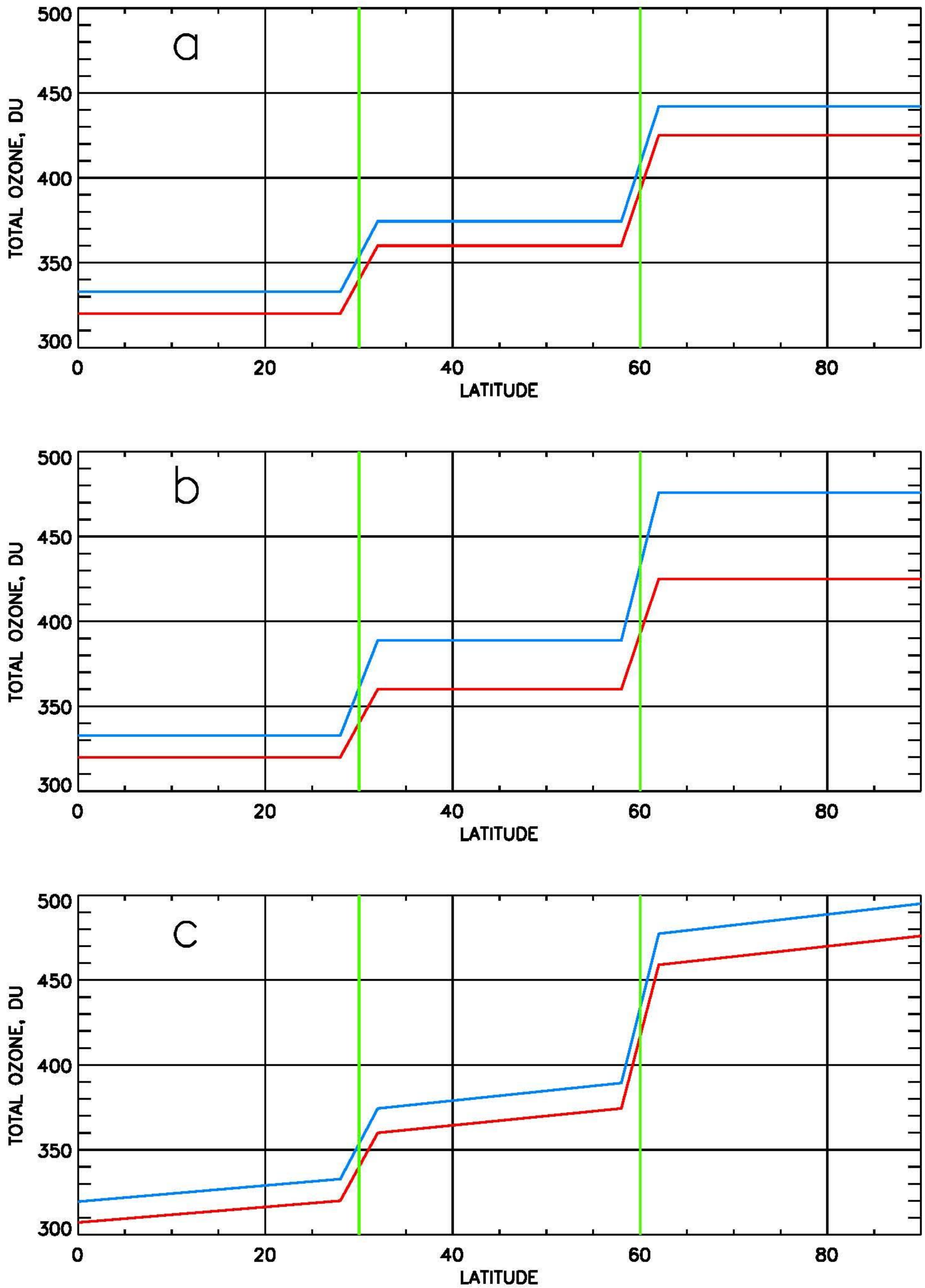
I do not totally agree with the conclusions of Binner 2010. Seidel and Randel in their analysis of the rawinsonde data have done the equivalent of the analysis reported in this paper. The tropopause heights used in their analysis are equivalent to the picture shown in Figure 1a of my previous response, not 1b. At each station they would encounter distinctly different tropopause heights, of the order of 16 km in the Hadley cell, 12 km in the Ferrel cell and 8 km in the Polar cell, as the Rossby waves move around the globe. I believe that the agreement between the Seidel analysis of the rawinsonde data and the analysis reported in the paper is significant.

I agree that the tropical surface temperature index I used could contain some signal from the radiative forcing. But it was pointed out to me that the ENSO (SST) index had a limited and fixed longitude range, whereas the maximum and minimum temperatures arising from El Nino and La Nina do not. I ran all of the 'SST' data sets I could find. The one I chose gave the best fit.

The choice of the lower stratosphere temperature index was based on the work of Lu et al. (2009). The MSU/AMSU data set for the tropical stratosphere covers a wide range of altitudes, while the Free et al. data set is given for specific altitude ranges. I ran the analysis for all of the Free et al. data sets and the MSU/AMSU data set. The 50 mb set of Free et al. gave the best fit.

I apologize for the confusion with Figure 5. The panels are sequential. In the first panels (N and S) I ran the regression program using the annual terms only, and determined the residual (measurement-fit) shown in red. I then ran the regression using the annual terms plus the radiative forcing. The blue line is the contribution from the radiative forcing to the new overall fit. In the second panel the red line is the residual for the annual terms plus radiative forcing. I then ran the program for the annual terms + radiative forcing + lower stratospheric temperatures; the blue line being the contribution of the temperature index. The other indices were then added sequentially. My purpose was to give the reader some idea of the quality of the fit. It should be noted that each panel does not represent the full set of indices except for the last set of panels.

Table 1 gives the regression constants using the full set of indices in the regression program


a
TOTAL OZONE, DU
500
450
400
350
300
0
20
40
60
80
LATITUDE
b
TOTAL OZONE, DU
500
450
400
350
300
0
20
40
60
80
LATITUDE
c
TOTAL OZONE, DU
500
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300
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LATITUDE

Figure X