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Quarterly Progress Report

on the

Utilization of UARS data in Validation of Photochemical and Dynamical Mechanism in Stratospheric Models

(Contract NAS5-32844)

by

Jose M. Rodriguez, Wenjie Hu and Malcolm K. W. Ko
Atmospheric and Environmental Research, Inc.
840 Memorial Drive, Cambridge, MA 02139

for

NASA Goddard Space Flight Center
Greenbelt, MD 20771

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1. Introduction

UARS data sets provide global coverage for the distributions of trace gases, which gives us an excellent chance to utilize the data set for model-data intercomparison studies. In the past three months, we have been working on the comparisons of the UARS data between 1992 (a half year after the Pinatubo eruption) and 1993 (one and a half year after the eruption) in an attempt to see how the Pinatubo volcanic eruption may have impacted stratospheric chemistry.

The intrusion of volcanic gases and particles to the stratosphere can have a significant impact on stratospheric chemistry (Rodriguez et al, 1994; Koike et al, 1994; Salawitch et al, 1994). The SO_2 and H_2O injected into the stratosphere will be converted to sulfuric acid quickly and provide sites for heterogeneous reactions. Heterogeneous reactions would activate chlorine and convert reactive nitrogen species into the more stable nitric acid (Rodriguez, et al, 1991). Meanwhile, the increased water vapor will lead to the enhanced OH and HO_2 which would further decrease NO_x and produce more HNO_3. Both these changes would change the ozone removal rate, especially in the middle latitudes. Following the arrival of the Pinatubo aerosols, a large decrease of NO_2 and increase of HNO_3 were observed at the surface stations of middle latitudes in both hemispheres (Johnston et al.,1992, Mills et al,1993, Koike et al,1993). Model calculations can produce behavior that quantitatively agree with the observed NO_2 and HNO_3 trends. However, the magnitude of the calculated changes are too small (Koike et al, 1994).

Before the availability of UARS data sets, observations of NO_2 and HNO_3 are limited to a few surface stations in both hemispheres, from which only column values are measured. Aircraft campaigns provided vertical profiles of some of the species, but all the measurements were limited to below 20km (AASE-II, *JRL* special issue, 1993, 1994; SPADE, *JRL* special issue, 1994). UARS data provides the information for altitudes higher than 20km. This allows us to determine whether the Pinatubo eruption would effect the atmospheric heterogeneous chemistry at altitudes above 20km.

2. Methodology for Data Analysis

For our analysis, we examined the observed ratio of NO_x/HNO_3 in 1992 and 1993 to determine if there is any significant difference due to the Pinatubo eruption. We used Level 3AT data from UARS CDROM (Version 7) to obtain the daily HALOE and CLAES data. Level 3AT data is organized by time along the orbit tracks. HALOE measures profiles for eight constituents (O_3, HCl, HF, CH_4, H_2O, NO, NO_2, and aerosols), temperature and pressure from about 15km to 60-150km, depending on channels (Russell et al, 1993). The vertical resolution is about 1.5 km at the earth limb. CLAES retrieves profiles of 13 species in the stratosphere O_3, H_2O, CH_4, N_2O, NO, NO_2, N_2O_5, HNO_3, $ClONO_2$, HCl, CFC-11, CFC-12 and aerosols) between 10km and 60km with a vertical resolution of 2.5km.

For our first analysis, we used the NO, NO_2 data from HALOE and HNO_3 data from CLAES. Because HALOE and CLAES data have different viewing geometries, they do not observe the same air mass. HALOE makes measurements twice per orbit: at sunrise and sunset. As UARS completes approximately 15 orbits each day, HALOE returns 30 profiles each day: 15 at sunrise and 15 at sunset. The HALOE measurements provide good longitudinal coverage on two latitudes circles daily, one corresponding to the sunrise locations, the other corresponding to the sunset locations. The vertical resolution is about 1.5 km at the earth limb. The latitudinal coverage is from 80°S to 80°N over the course of one year. CLAES views daily from 34° latitude on one side of the equator to 80° in the other since UARS orbit has 57° inclination. UARS performs yaw cycles every 36 days, viewing the northern and southern high latitudes alternately. Data are collected at different local times as the scan is performed along different latitudes. The daily HALOE and CLAES orbits are shown in Figure 1. The HALOE measurements are illustrated using larger dots. The two latitude circles viewed by HALOE may not necessarily lie within the latitudinal range of CLAES on any given day.

Since the NO and NO_2 quality of HALOE data is better than those of CLAES, we used HALOE locations for overall analysis, interpolating CLAES data to get HNO_3 values at the closest location to HALOE measurements on the same day. HALOE data has a good longitudinal coverage. To minimize the data variability, we averaged them over zonal direction. As a start, we simply averaged all CLAES measurements that are within 5 degree latitude of a HALOE sampling point on the same day. Typically, there are between 5 to 10 points.

Since the diurnal variation of HNO_3 is small between 20 and 30 km and the local times of CLAES measurements are close to each other, the averaged value is relatively good representation of the HNO_3 value at the HALOE sampling point.

3. Comparison Results and Discussion

January, February in 1992, 1993 have been chosen for comparisons since CLAES was south-viewing (34N-80S) during that time, and it was southern hemisphere summer and the measurements are less effected by the large wave-breaking events that normally occur in winter.

The data were aggregated in 10 degree latitudinal bins to get the zonally averaged vertical profiles for NO_2, HNO_3 and NO_x to HNO_3 ratio. The comparisons between '92 and '93 for different latitudinal bins are shown in the following figures. We expected a stronger volcanic effect to show in '92 data, which was only a half year later after the eruption. The standard deviations are calculated and affect plotted in the same figures. Volcanic aerosols are expected to effect stratospheric heterogenous chemistry between 20-30km.

The zonally means and standard deviations(deviations of mean values over averaging periods) of HNO_3, NO_2 and ratio NO_x/HNO_3 at middle latitudinal bins 20S-30S, 30S-40S, 40S-50S, 20N-30N, and 30N-40N are shown in figure 2 to figure 6. We can see that:

(1) CLAES HNO_3 data shows larger values above 31.6mb at middle latitudinal bins in January and February '92 than those in 1993. The differences between '92 and '93 data vary about 0.5-1.0 ppb from 6.8mb to 31.6mb. Below 31.6mb, HNO_3 data shows no obvious differences between '92 and '93 data. The standard deviations between '92 and '93 are not totally separated.

(2) At latitudinal bins 20N-30N, 20S-30S, 30S-40S, there is no obvious difference in the NO_2 data between '92 and '93. However, at latitudes 40S-50S, NO_2 is 0.5-1.2ppb smaller from 6.8mb to 31.6 mb in '92; at latitudes 30N-40N, NO_2 is smaller from 6.8mb to 21.5mb in '92.

(3) NO_x/HNO_3 ratios is smaller above 21.5mb in '92 at most latitudinal.

Even though the mean values of UARS data show stronger heterogeneous chemistry effects just after the volcanic aerosols reached the the middle stratosphere in '92, the error bars (standard deviations) between '92 and '93 data still overlap. To explain the UARS measurement, further studies are necessary. For instrance, it is important to ascertain whether the differences between the '92 and '93 data are consistent with the expected behavior of the heterogeneous reactions and their saturation.

4. Future Works

We plan to use the UARS data in our chemistry box models to see if the observed behavior is consistent with model predictions. We will use additional data from UARS to constrain the model. Since the data are not necessarily from the same air mass, care must be taken to allow for the different locations and local times. For long-lived trace gases, we plan to use the trajectory mapping technique developed by Morris et al (1995) to transfer the data. For species with large diurnal variations, we will use the box model to adjust for the local time.

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Figure 1. CLAES HNO_3 measurement on 1/18/92 is shown at 850K isentropical surface. The small dots show CLAES track. Large dots are HALOE sampling points on the same day.

Figure 2 The zonally averaged HNO_3, NO_2 and NO_x/HNO_3 vertical profiles at 20S-30S latitudinal zone in January and February '92 and '93 when UARS was south-viewing. HNO_3 data is from CLAES. NO and NO_2 data are HALOE measurements.

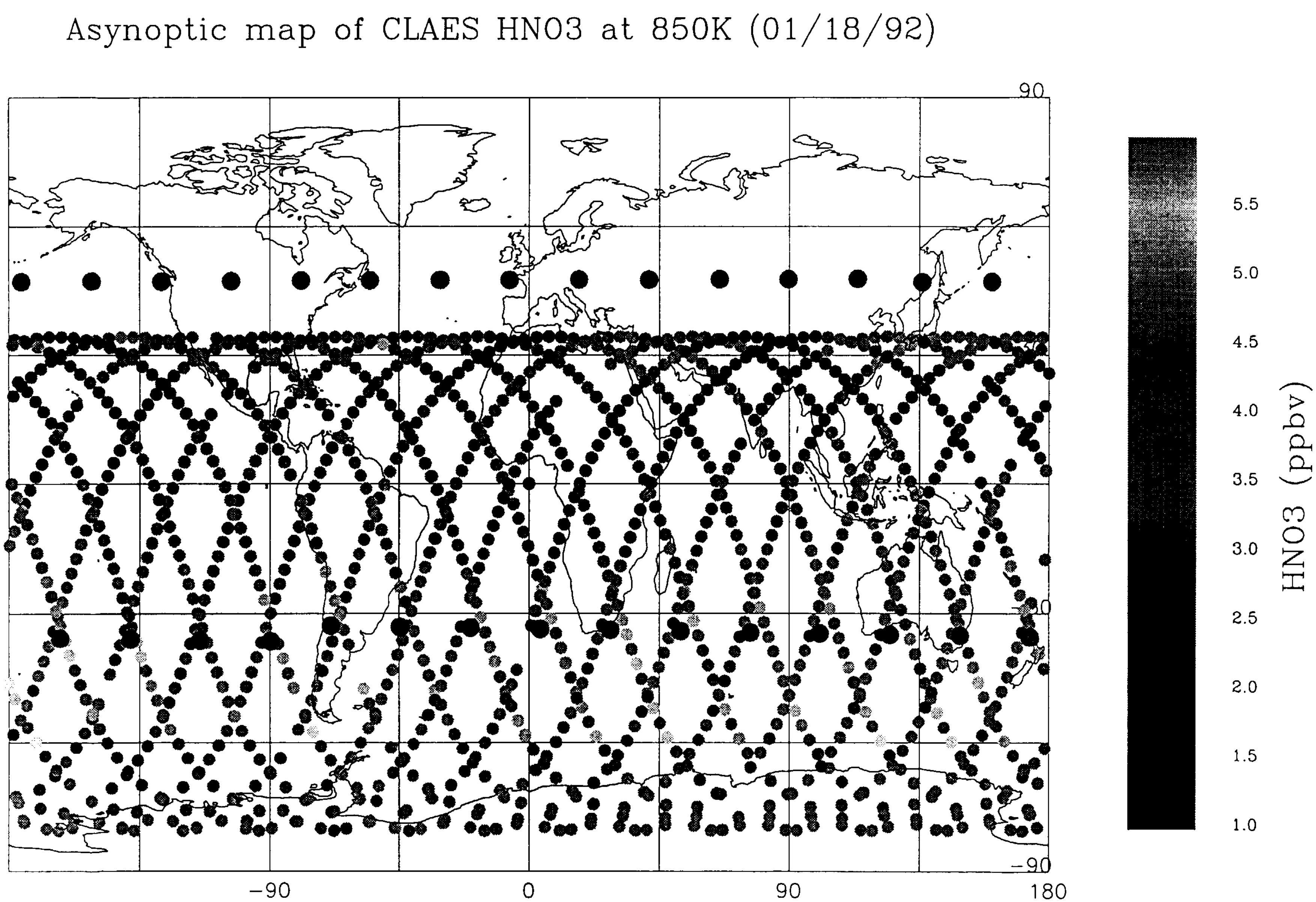
Figure 3. Same as Figure 2 but for 30S-40S latitudinal zone.

Figure 4. Same as Figure 2 but for 40S-50S latitudinal zone.

Figure 5. Same as Figure 2 but for 20N-30N latitudinal zone.

Figure 6. Same as Figure 2 but for 30N-40N latitudinal zone.

Figure 7. The difference of SAGE II aerosol surface areas between January '92 and January '93. The negative contours mean the '92 data is smaller.



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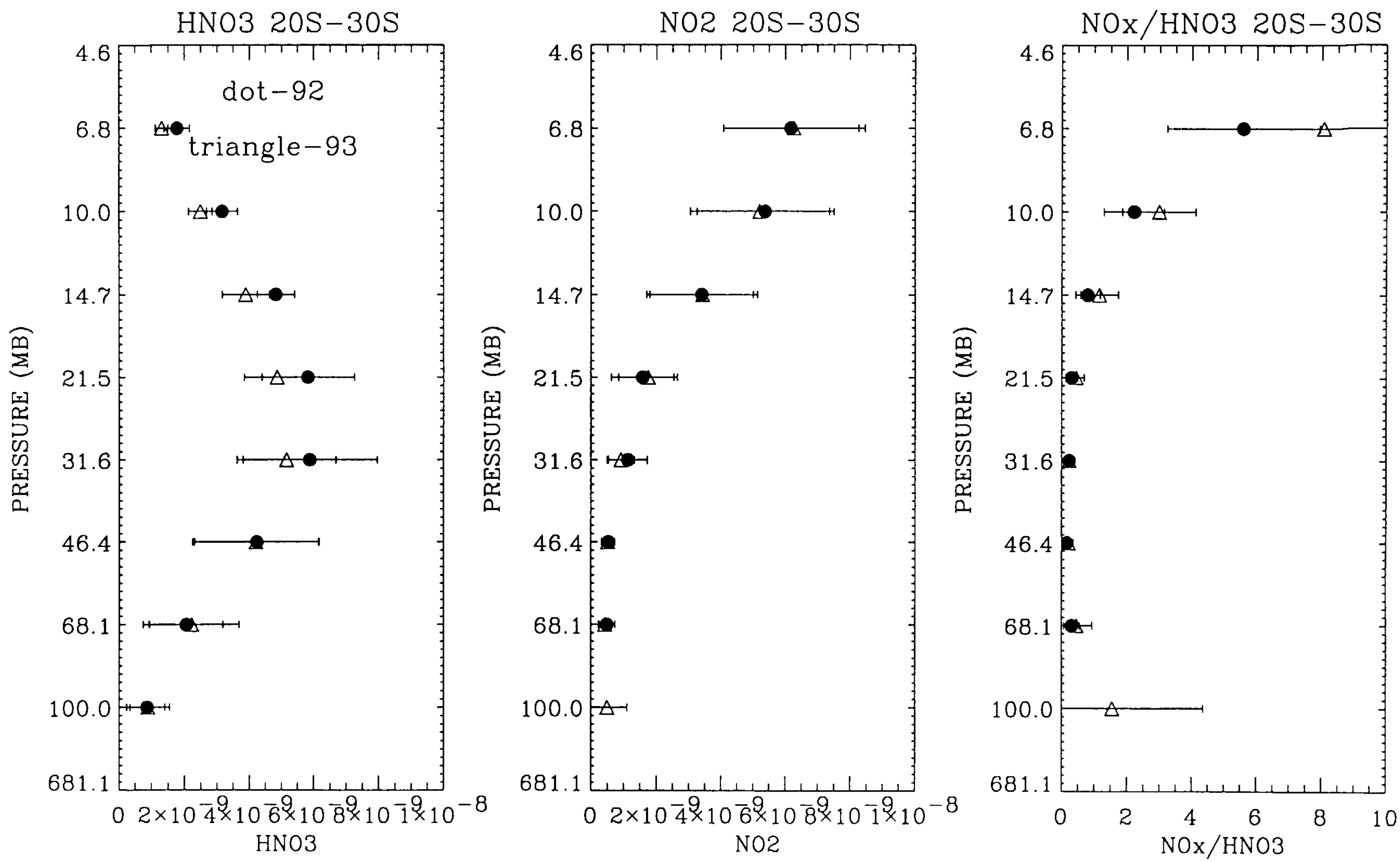

Figure 2: The zonally averaged HNO3,NO2 and NOx/HNO3 vertical profiles at 20S-30S latitudinal zone in Jan. and Feb., 1992 and 1993 when UARS was south-viewing. HNO3 data is from CLAES. NO and NO2 data are HALOE measurements.

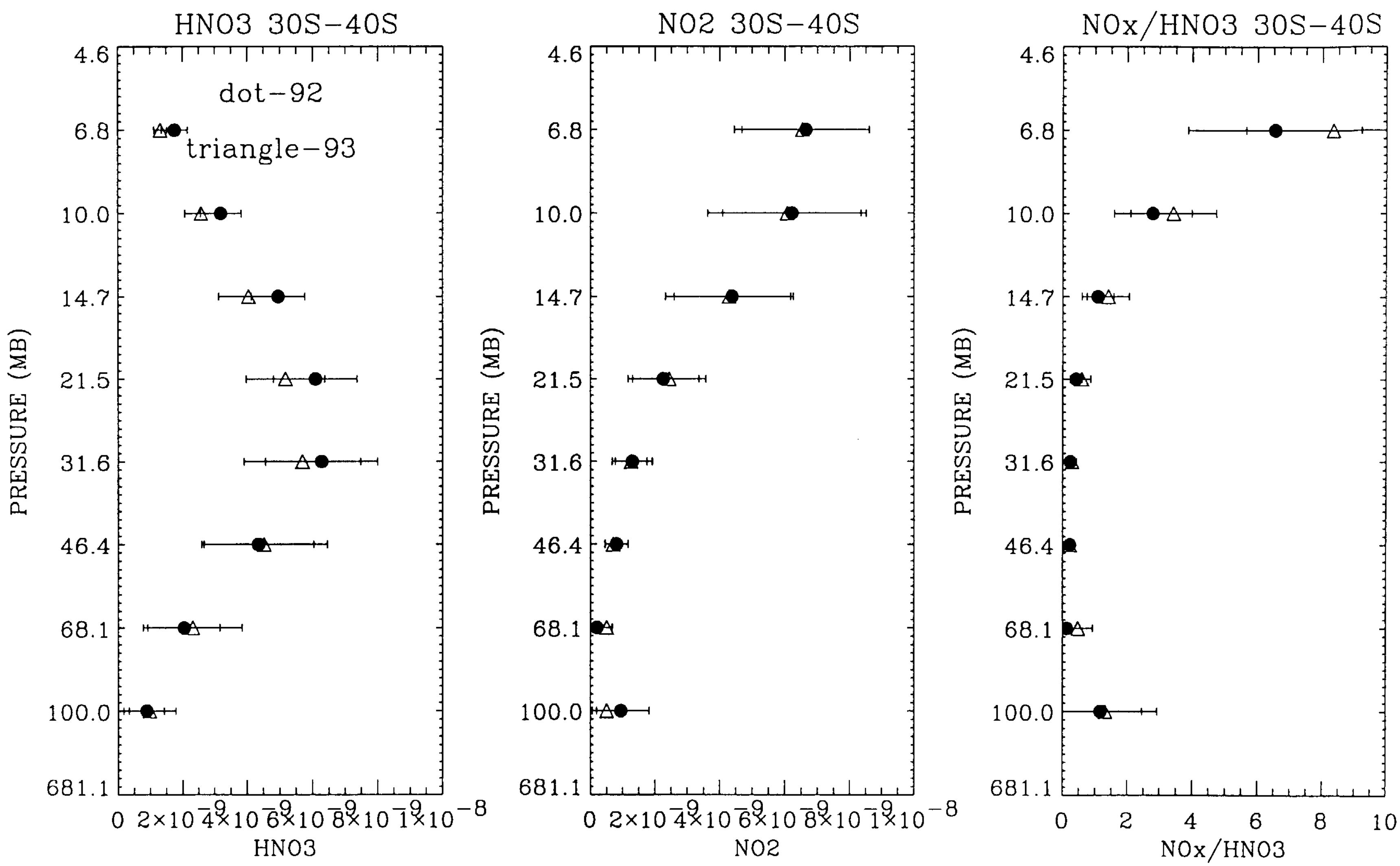

Figure 3: Same as Figure 2 but for 30S-40S latitudinal zone.

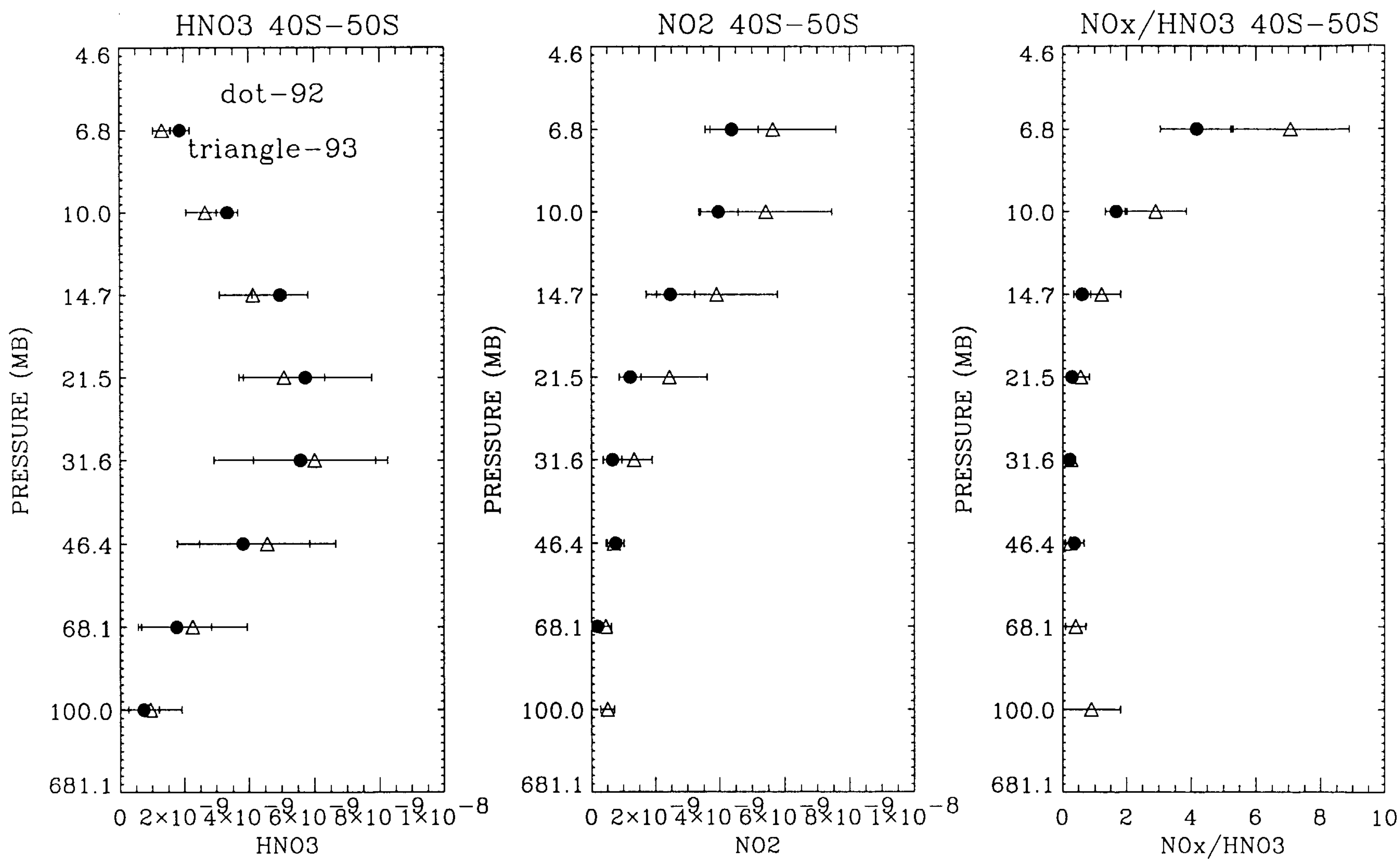

Figure 4: Same as Figure 2 but for 40S−50S latitudinal zone.

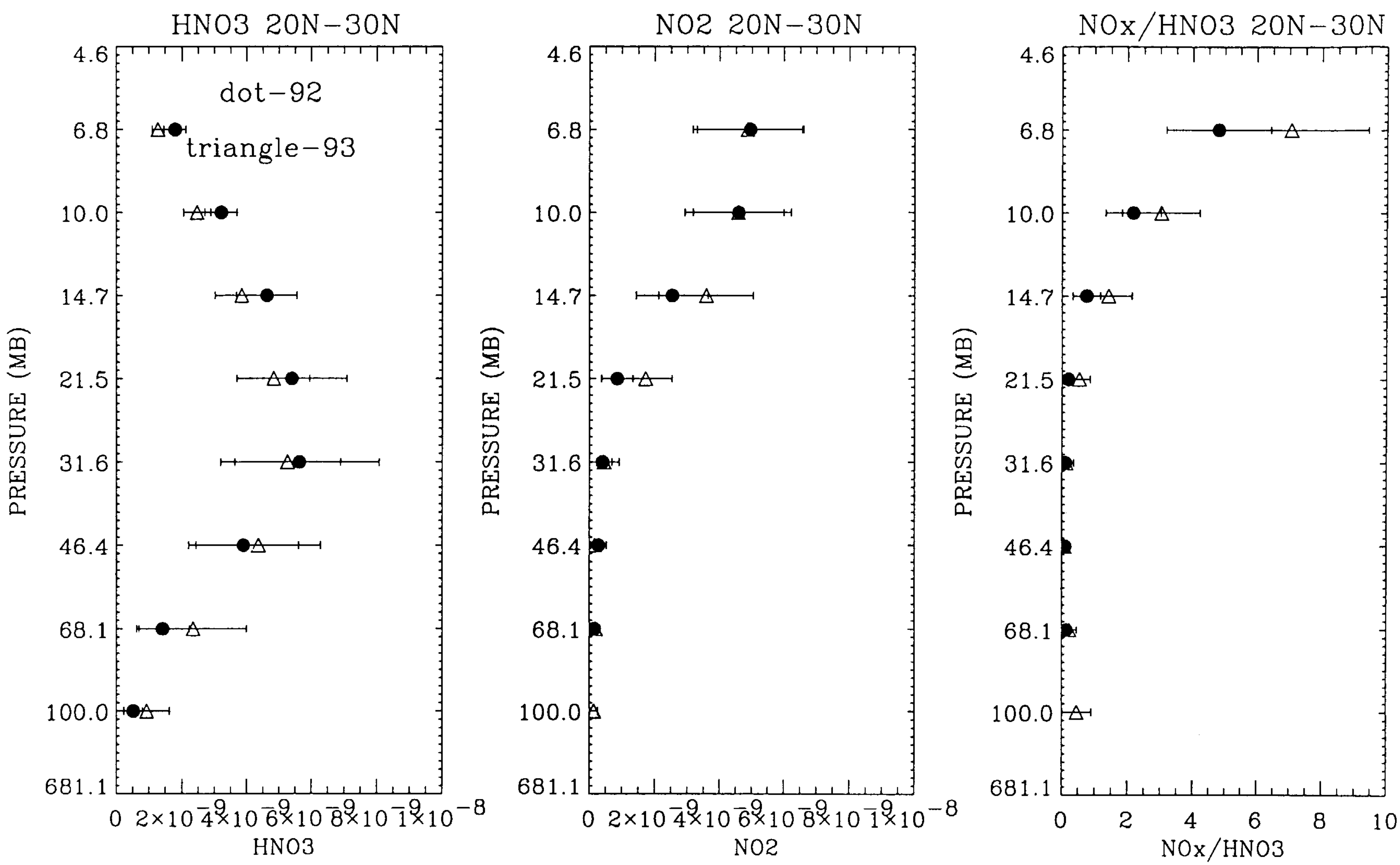

Figure 5: Same as Figure 2 but for 20N−30N latitudinal zone.

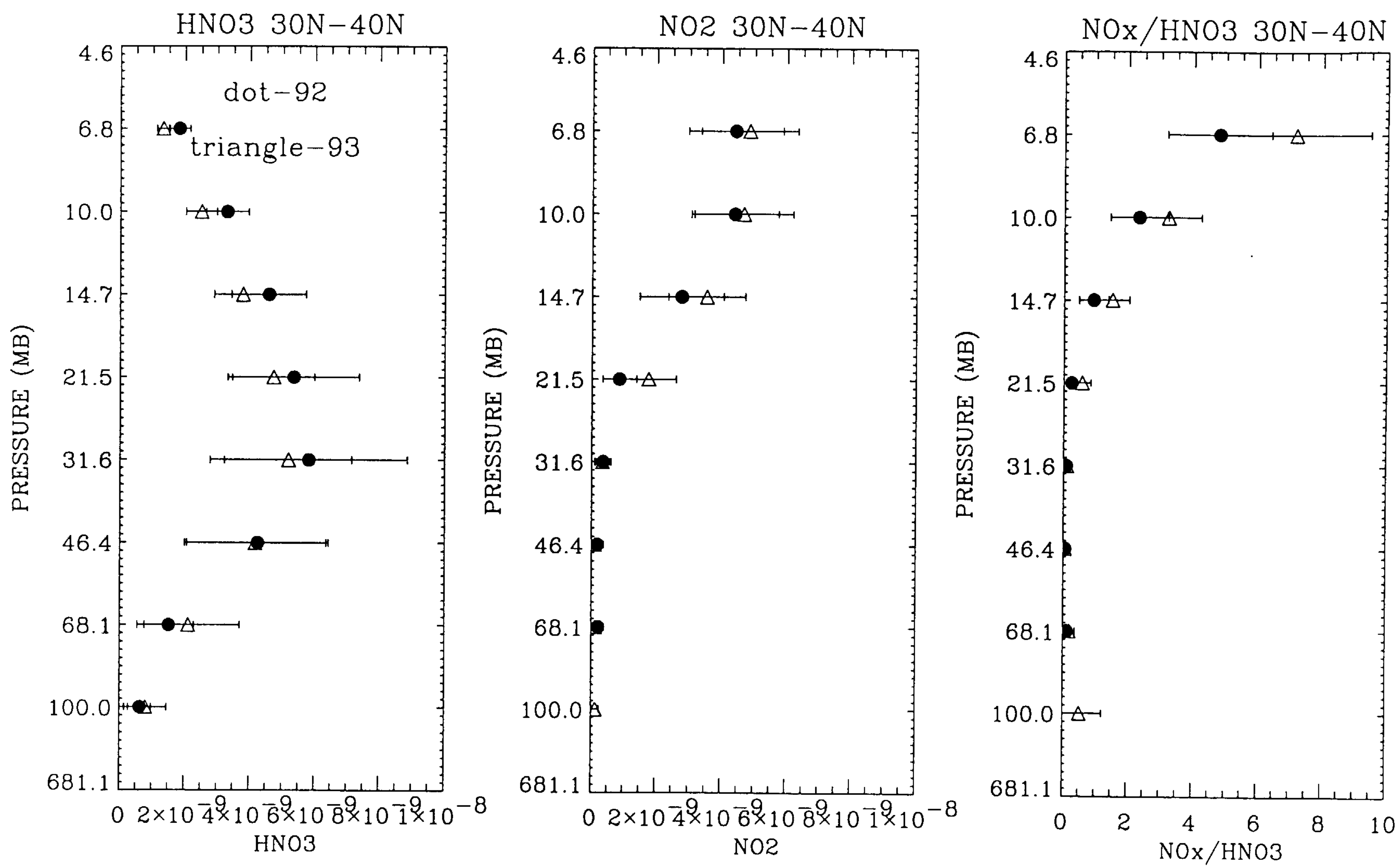

Figure 6: Same as Figure 2 but for 30N−40N latitudinal zone.

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13. ABSTRACT *(Maximum 200 words)*

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