

I N S T I T U T D ' A E R O N O M I E S P A T I A L E D E B E L G I Q U E

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of the Spacelab one grille spectrometer

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B E L G I S C H I N S T I T U U T V O O R R U I M T E A E R O N O M I E

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FOREWORD

This text will be presented at the Fall Meeting of the American Geophysical Union (December 3-7, 1984).

AVANT-PROPOS

Ce texte sera présenté à la réunion d'automne de l'American Geophysical Union (3-7 décembre 1984).

VOORWOORD

Deze tekst zal voorgesteld worden tijdens de herfstvergadering van de American Geophysical Union (3-7 december 1984).

VORWORT

Dieser Text wird präsentiert werden während der Herbsttagung der American Geophysical Union (3-7 Dezember 1984).

MIDDLE ATMOSPHERIC NO AND NO₂ OBSERVED BY MEANS OF THE
SPACELAB ONE GRILLE SPECTROMETER

by

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Abstract

During the course of the Spacelab One Mission in November-December 1983 infrared spectra of the earth atmospheric limb were obtained in absorption using the setting and rising sun as a source. One run taking place in the southern hemisphere at sunrise was dedicated to the simultaneous observation of NO from 20 to 100 km altitude and of NO₂ from 20 to 42 km altitude. The stratospheric profiles are in agreement with previous measurements. The mesospheric NO abundance exhibits a maximum near 90 km altitude and a minimum near 62 km altitude. The NO volume mixing ratio increases at least 1000 times from 60 to 100 km altitude where a value of 10⁻⁵ is reached.

Résumé

Au cours de la première mission de Spacelab en novembre-décembre 1983 des spectres d'absorption infrarouge du limbe atmosphérique furent obtenus en utilisant le soleil levant et couchant comme source. Une observation était consacrée dans l'hémisphère sud au lever à l'observation de NO de 20 à 100 km d'altitude et de NO_2 de 20 à 42 km d'altitude. Les profils de concentrations stratosphériques obtenus sont en accord avec les résultats antérieurs. Le NO mésosphérique montre un maximum de concentration près de 90 km d'altitude et un minimum près de 62 km d'altitude. La concentration volumique de NO croît d'un facteur 1000 de 60 à 100 km où elle atteint 10^{-5} .

Samenvatting

Tijdens de eerste vlucht van het Spacelab in november-december 1983 werden infrarode absorptiespectra van de atmosferische kim bekomen door de zon bij haar opgang en ondergang als bron te gebruiken. Eén waarneming in de zuidelijke hemisfeer bij zonsopgang was gewijd aan de gelijktijdige waarneming van NO van 20 tot 100 km hoogte en van NO_2 van 20 tot 42 km hoogte. De bekomen profielen van stratosferische concentraties stemmen overeen met voorgaande resultaten. De mesosferische NO vertoont een maximumconcentratie bij 90 km hoogte en een minimum bij 62 km hoogte. De volumeconcentratie van NO stijgt met een factor 1000 van 60 tot 100 km hoogte waar een waarde van 10^{-5} bereikt wordt.

Zusammenfassung

Während des ersten Fluges des Spacelabs im November-Dezember 1983 wurden infraroten Absorptionspektra der Erdenrandes bekommen mit der Sonne bei ihren Aufgang und Untergang als Quelle zu gebrauchen. Eine Beobachtung in der südlichen Hemisphäre beim Sonnenaufgang war verbunden an der gleichzeitige Beobachtung der NO von 20 bis 100 km Höhe und der NO_2 von 20 bis 42 km Höhe. Die bekommen Profilen von stratosphärischer Konzentrationen stimmen überein mit vorigen Resultaten. Das mesosphärische NO zeigt eine Maximumkonzentration bei 90 km Höhe und ein Minimum bei 62 km Höhe. Die Volumenkonzentration von NO steigt mit einem Faktor 1000 von 60 bis 100 km Höhe wo ein Wert von 10^{-5} erreicht wird.

INTRODUCTION

After Nicolet (1945) suggested the presence of nitric oxide in the upper atmosphere as a source of the D region ionization by the solar Lyman α radiation, it took almost 20 years until this trace species be observed (Barth, 1964). This was achieved through the resonance fluorescence method. Nearly 10 years later, the vertical distribution of nitric oxide was observed in the stratosphere by means of balloon borne infrared absorption spectrometry (Ackerman et al., 1973).

Since then much emphasis has been put on odd nitrogen compounds in the stratosphere in relation with their role in controlling the odd oxygen stationnary abundance in the form of ozone. Many stratospheric measurements have been performed of NO, NO_2 , HNO_3 , NO_3 with inferences on the N_2O_5 abundance. Meanwhile several determinations of NO in the mesosphere and in the low thermosphere have been performed (Meira, 1971; Tisone, 1973; Witt et al., 1976; Tohmatsu and Iwagami, 1975; Baker et al., 1977 and Thomas, 1978) based on resonance fluorescence and by means of mass spectrometers (Trinks et al., 1978).

We wish to report here the first "one shot" observation of NO from the low thermosphere down to the low stratosphere. This was done by means of a similar instrumentation as the one used previously on board of balloon gondolas. This time, however, the observation platform being Spacelab one, the access to higher altitudes was possible. As before (Ackerman et al., 1975) NO and NO_2 were observed simultaneously.

OBSERVATION

The infrared grille spectrometer flown on board of the space shuttle during the first Spacelab mission has already been described (Lemaître et al., 1984). In the course of this mission, one earth limb solar occultation run was devoted to the observation of NO and NO₂ in the respective wavenumber ranges : 1914.5 - 1918 cm⁻¹ and 1595 - 1598.5 cm⁻¹. The corresponding wavelengths were selected in the 6th and 5th orders of the grating, as shown in figure 1, by two interference filters, one for each of the two liquid nitrogen temperature cooled detectors.

This observation took place over the southern Pacific ocean on December 1, 1983. The geographic coordinates of the tangent points of the solar rays reaching the instrument to the geoïd's enveloppes at 20 and 100 km altitude are shown on figure 2. This figure shows the solar elevation angle versus time at the two geographic locations. The observations took place at sunrise after the very short nights of the high southern latitudes in the late fall. For the 20 km and 100 km tangent altitude locations, the sun depression angles do not exceed 0.3° and 1.4° respectively in the course of the day. Thus the observations took place in nearly full daylight conditions with practically all the odd nitrogen in the form of NO in the mesosphere and in the form of NO, NO₂ and HNO₃ in the stratosphere according to our present knowledge of the atmospheric photochemistry.

The spectra of which samples are shown in figures 3 and 4 for NO and NO₂ were recorded every two seconds. The measured equivalent widths are shown in figures 5 and 6 versus tangent heights in the atmosphere.

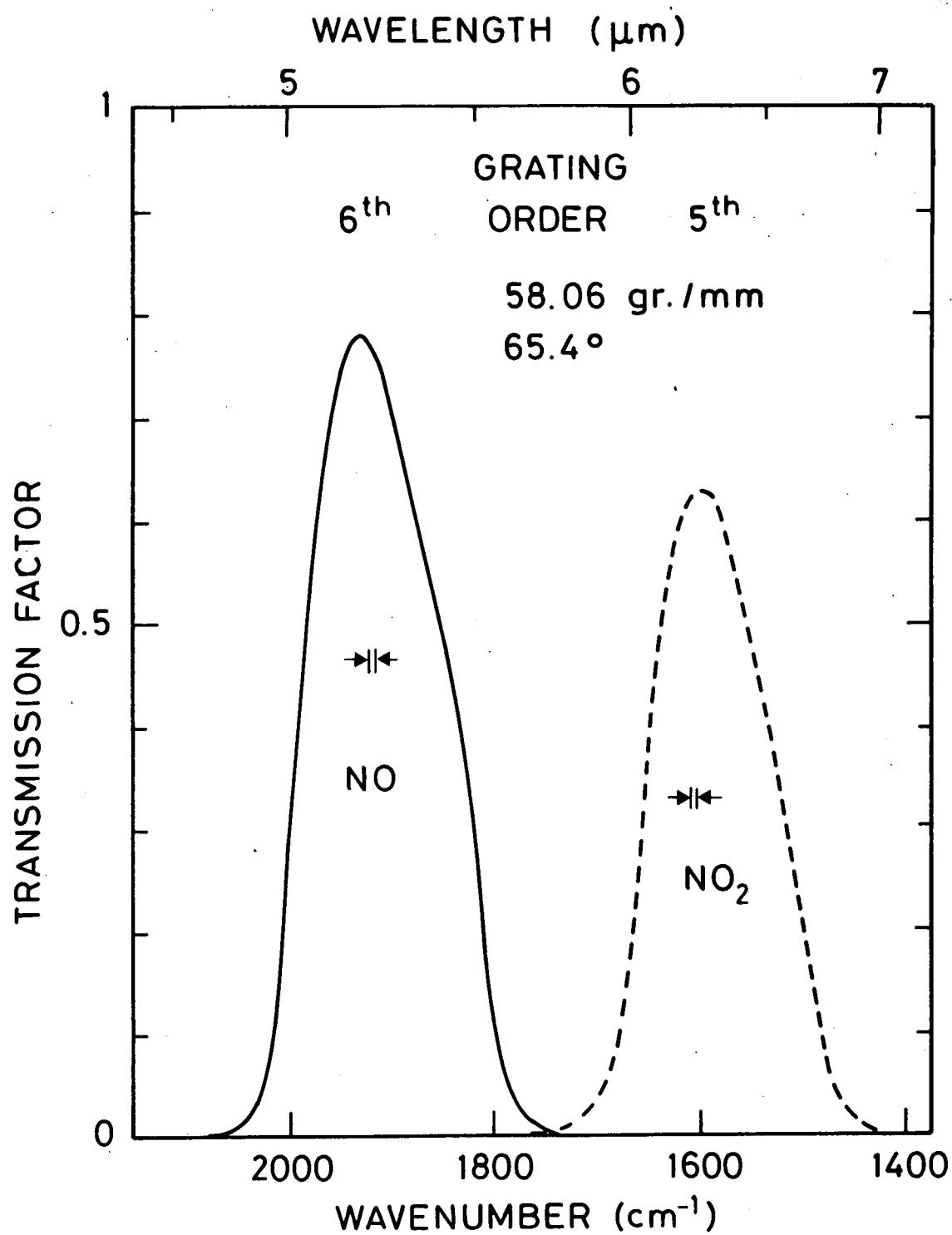


Fig. 1.- Transmission factor versus wavenumber and wavelength of the interference filters selecting the 5th and 6th orders of the grating. The narrow spectral ranges used for the determination of NO and NO_2 are illustrated.

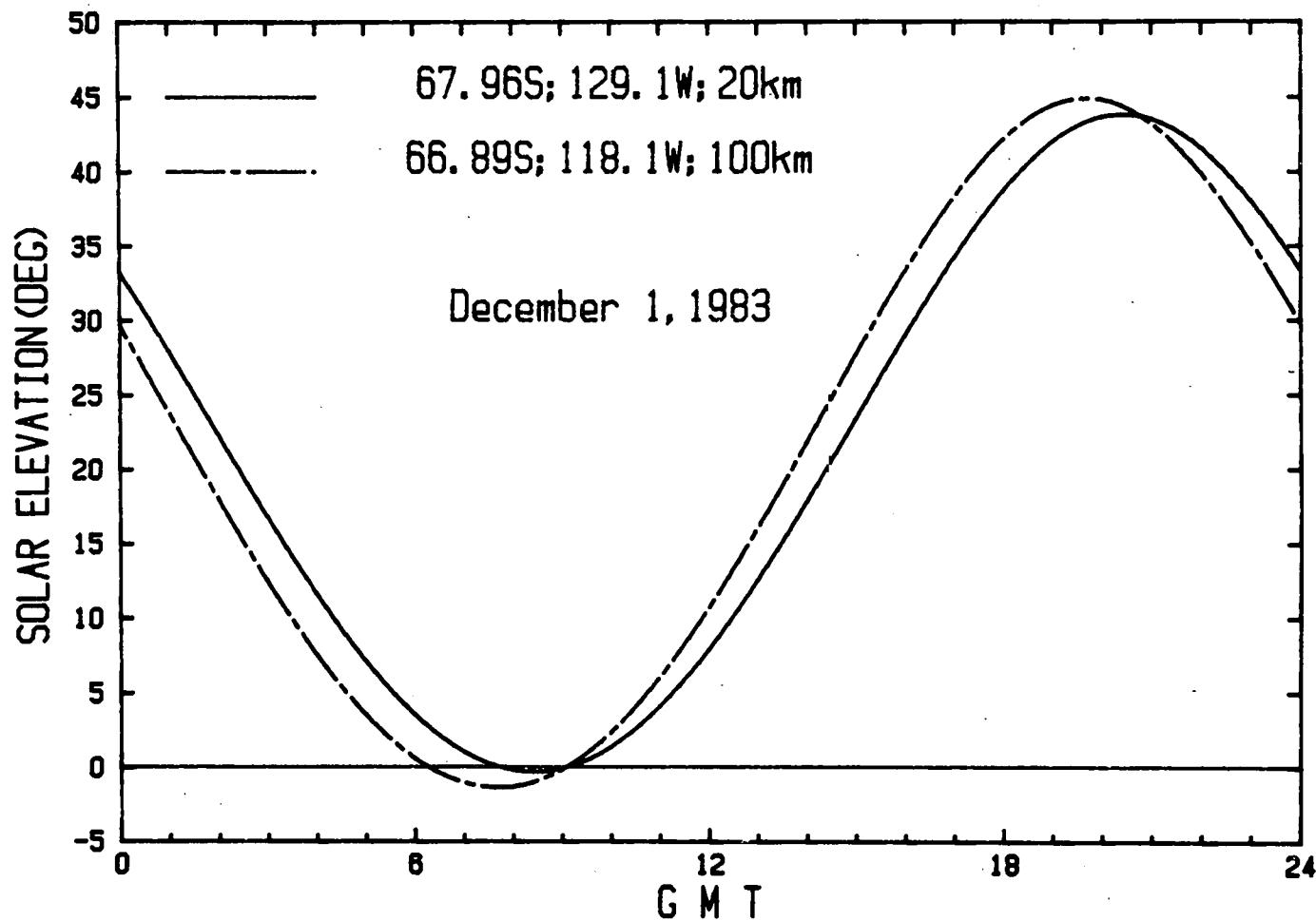


Fig. 2.- Solar elevation versus time in hours (G.M.T.) for December 1, 1983 and the geographic location of the tangent points at 20 and 100 km altitude of the solar rays to the instrument. The observation took place at sunrise from 9h03 min 38 sec to 9hr4 min 52 sec G.M.T. for the sun grazing altitudes from 20 to 100 km. The nearly whole day, full sunlight condition of the atmosphere is obvious.

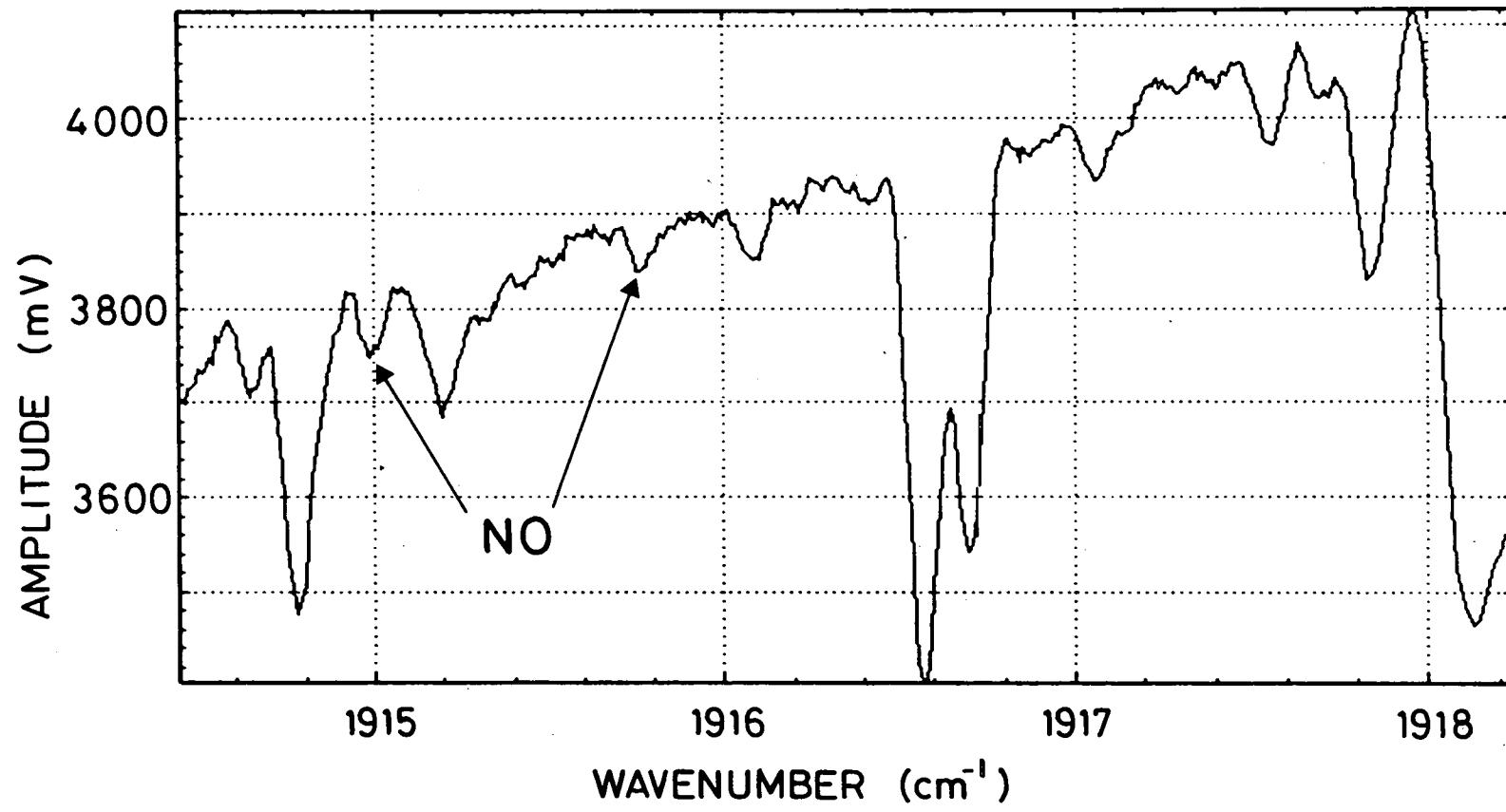


Fig. 3.- Solar spectra recorded at sunlight tangent altitude equal to 86 km. Two NO absorption lines are indicated.

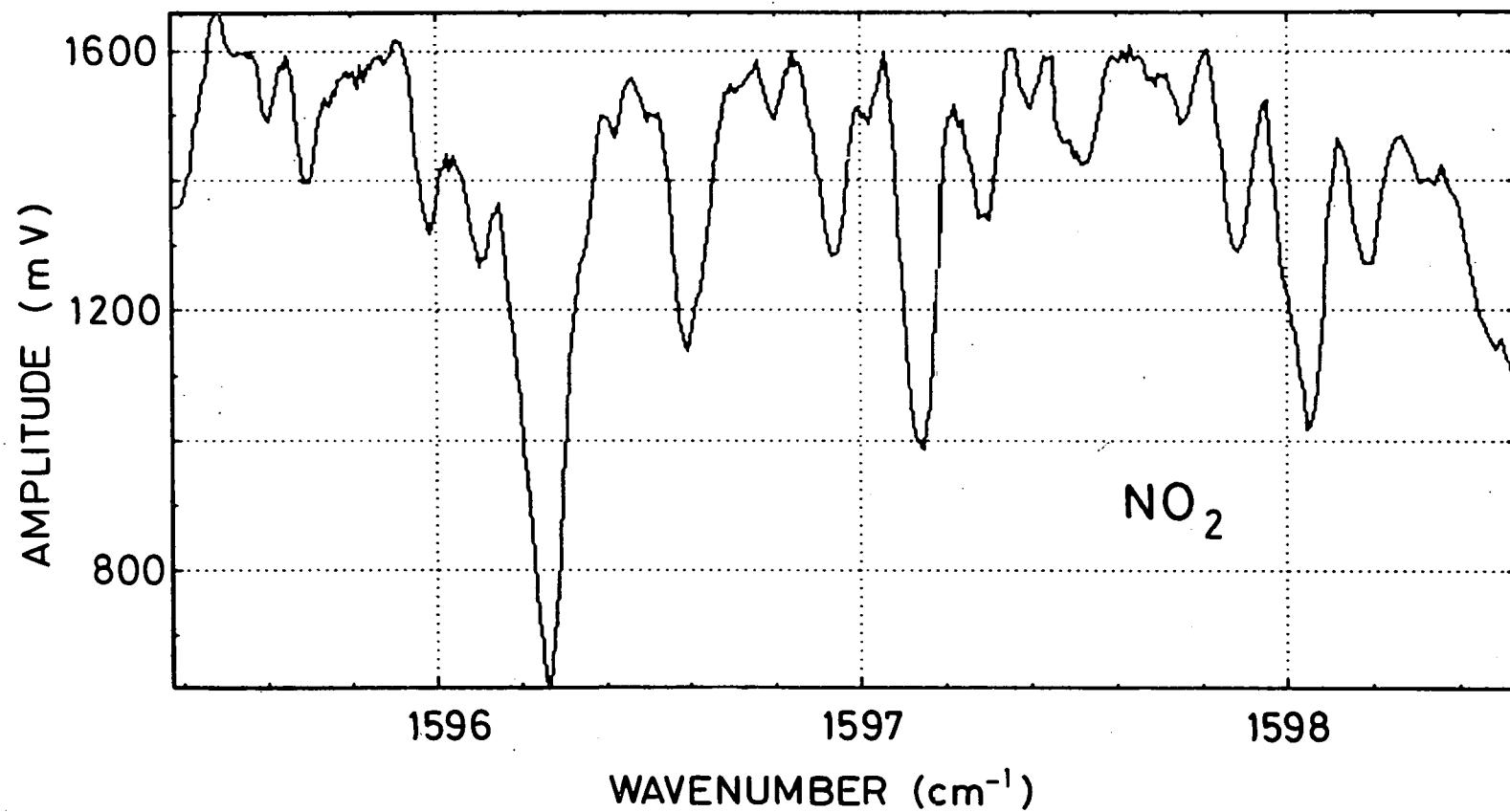


Fig. 4.- NO₂ absorption spectrum recorded at sunlight tangent altitude equal to 26 km.

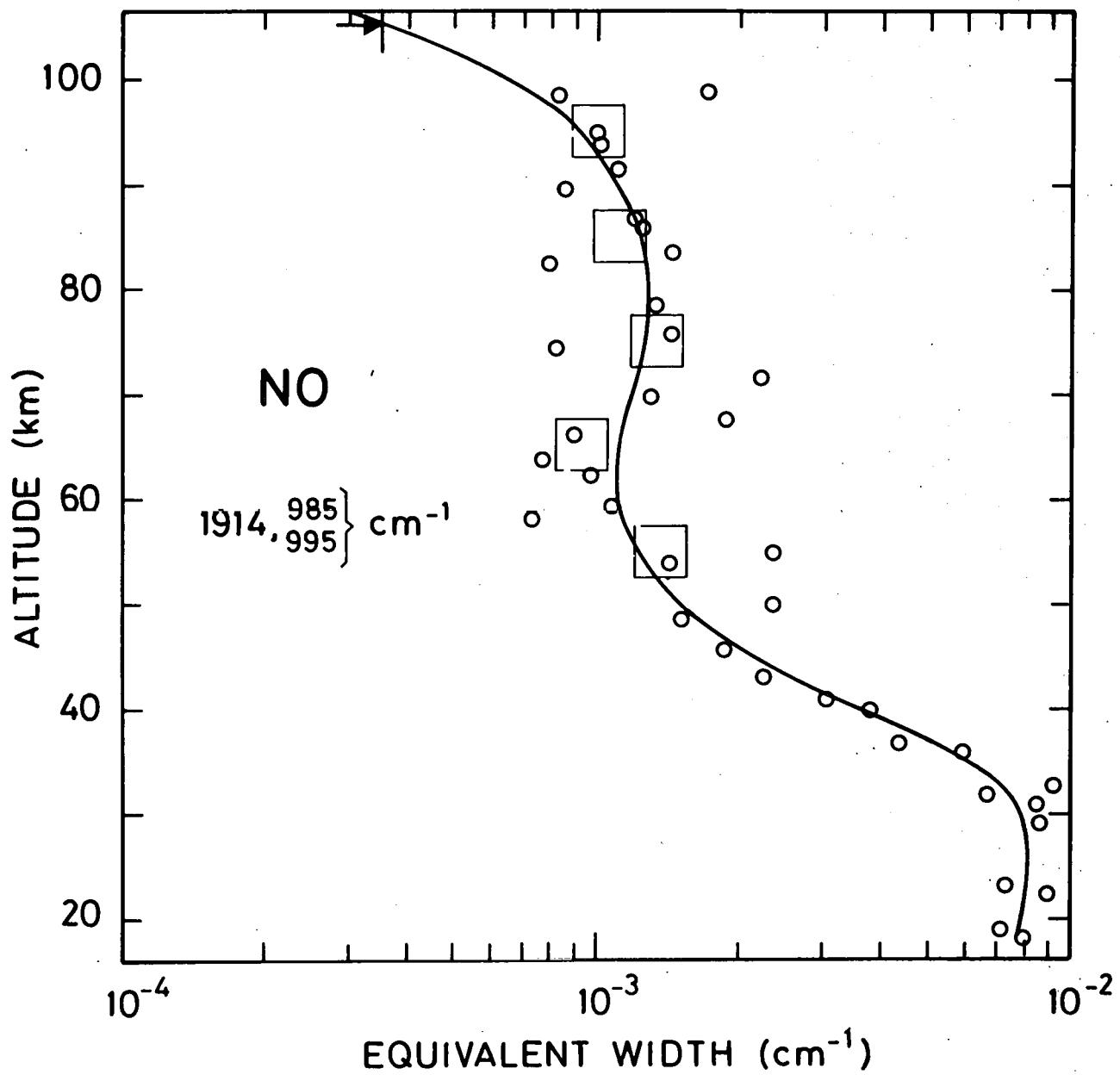


Fig. 5.- Equivalent widths versus grazing sunlight altitude
for the NO absorption doublet at 1914.99 cm⁻¹.
The squares represent five kilometers averages.

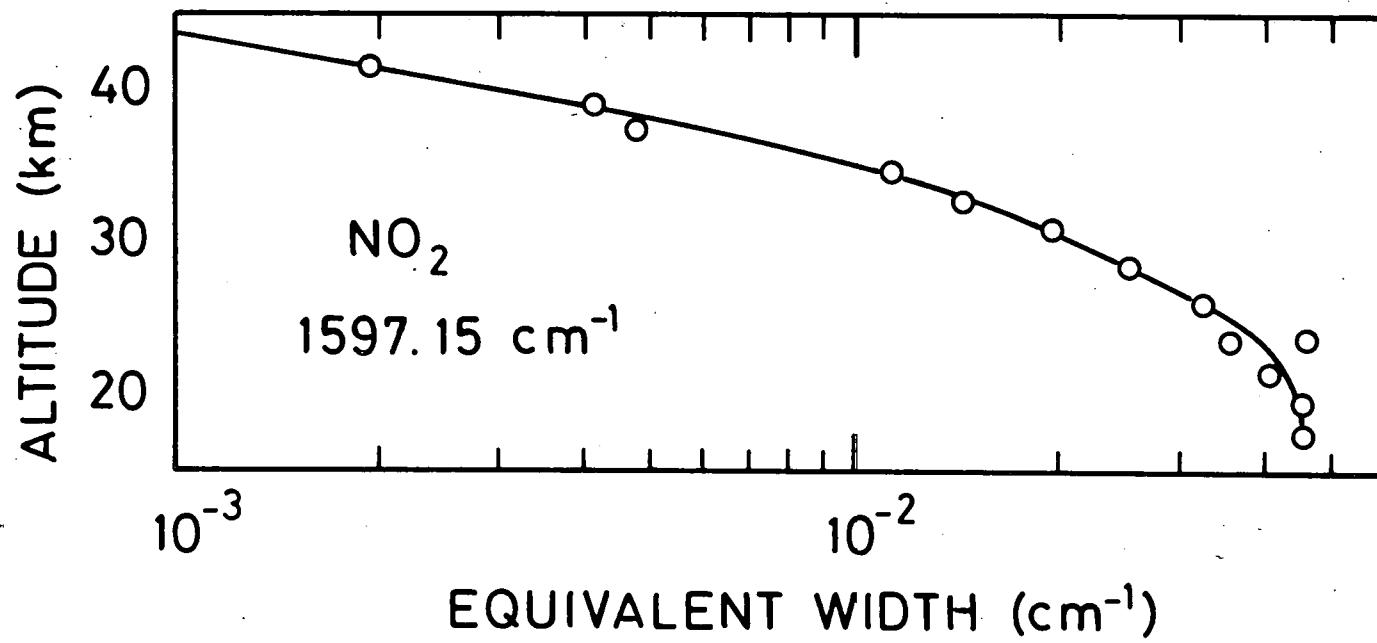


Fig. 6.- Equivalent width versus grazing sunlight altitude
for the NO₂ multiplet center at 1597.15 cm^{-1} .

The inversions of the data represented by the smooth curves in figures 5 and 6 was made using the molecular line parameters of Rothman et al. (1983). They lead to the vertical distributions of NO and NO_2 shown in figure 7. Above 98 km altitude, the scanned wavelength intervals were broadened in order to observe broader band solar spectra. The 1914.99 cm^{-1} NO line region was observed again at 105 km tangent altitude where the NO signal was too weak to be detected. From 55 to 75 km altitude a dashed line represents inverted NO number densities so low that the slant absorption has to be attributed to NO at higher altitudes. Hence from 55 to 75 km altitude the NO abundance can only be tentatively given corresponding more to a shallow upper limit.

DISCUSSION AND CONCLUSION

The stratospheric portion of the observation may be characterized by a high signal to noise ratio for the absorption lines. Hence, the uncertainty on the volume concentrations is small and the values are in the range of previous observations. They will be discussed elsewhere.

For the sake of comparison with other observations in the mesosphere and in the low thermosphere the results are shown in figure 8 with those published by other authors. The night NO_2 upper and lower abundances in the mesosphere observed by means of the limb infrared monitor of the stratosphere (LIMS) on board of the Nimbus 7 satellite at high northern latitude in winter are also shown (Russel et al., 1984). The odd nitrogen should in this case be mostly in the form of NO_2 providing a source of data suitable for comparison with ours.

If our results show a rather good agreement with other observations at the highest altitudes the differences become very large at 85 km particularly with the vertical profiles exhibiting a minimum

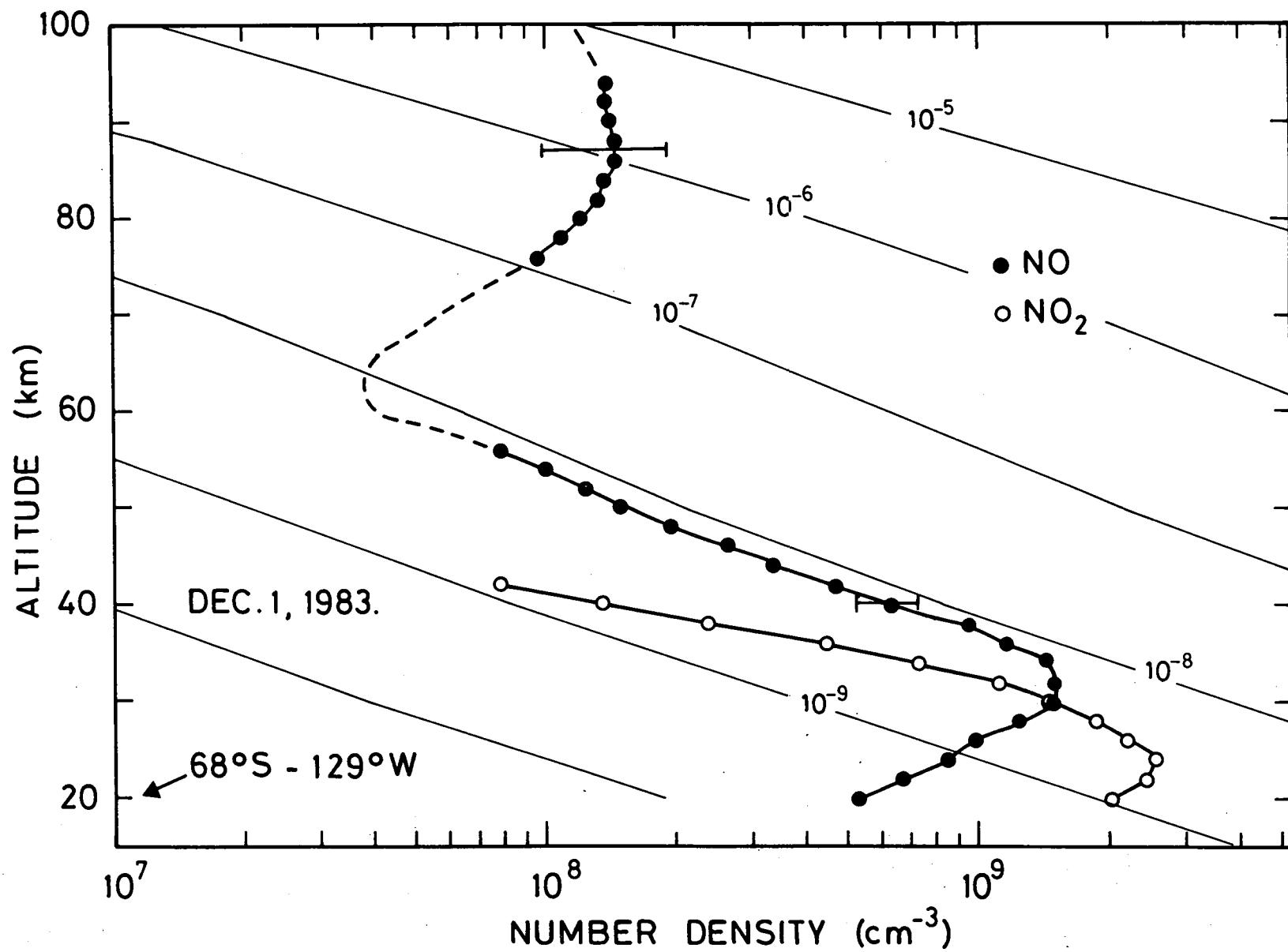


Fig. 7.- Number densities of NO and NO₂ versus altitude. The near straight lines indicate constant volume mixing ratios from 10^{-10} to 10^{-5} .

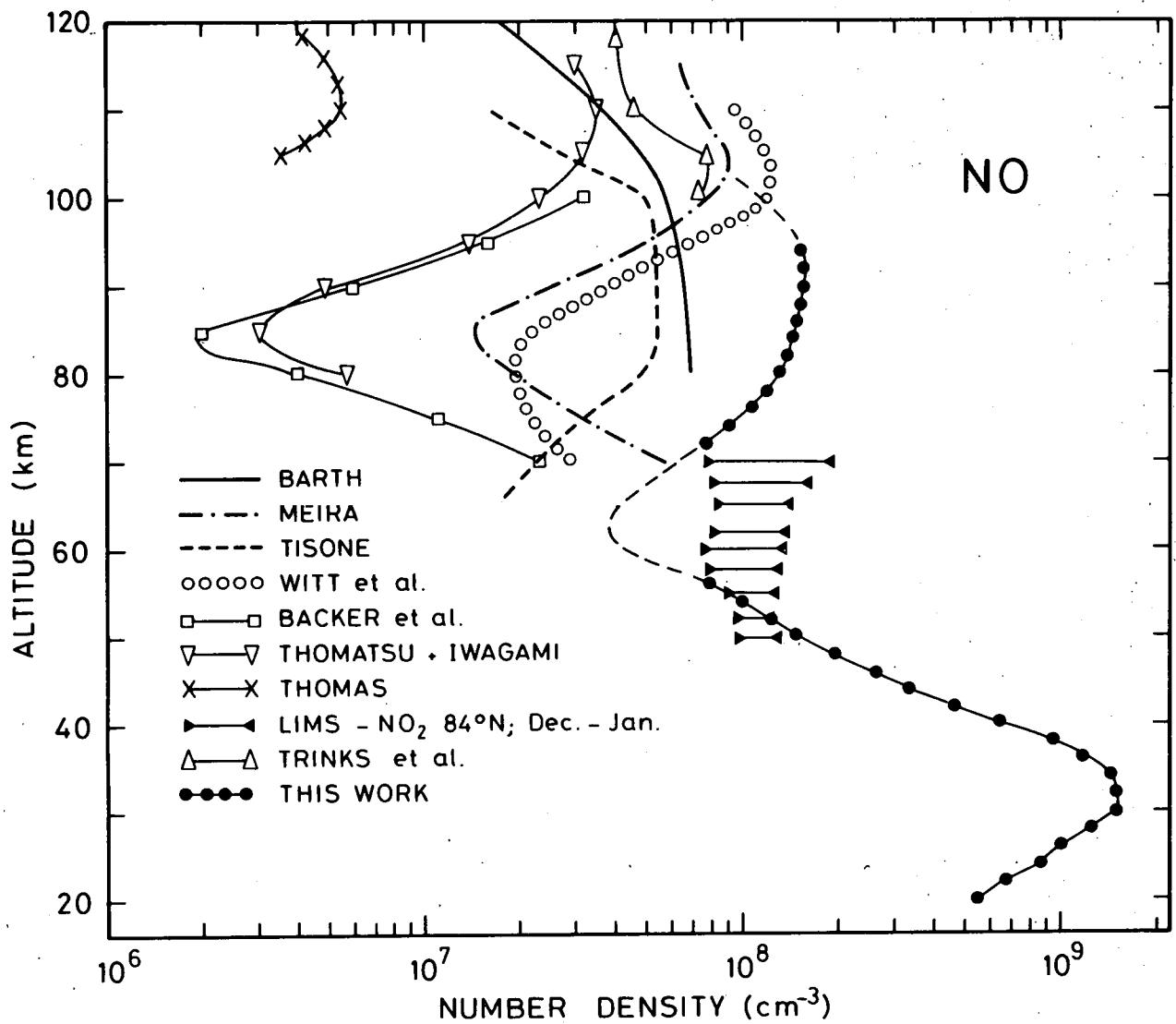


Fig. 8.- Nitric oxide number densities presented in this paper with results of other authors. The mesospheric NO_2 LIMS upper and lower values observed in December-January at high northern latitudes are also shown (see text).

volume concentration at that altitude. The shape of the vertical profile compares in the best fashion with the results of Barth (1964) and Tisone (1973). The NO₂ LIMS results tend to support our high values.

Slight modifications of the new data presented here may occur if more refinement was to alter significantly the orbit parameters of the shuttle during the first Spacelab mission. More observations will be possible when the instrument will be flown in a mission more dedicated to atmospheric studies. They should shed some usefull light on the presently intricate picture of the mesospheric NO as illustrated in figure 8.

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