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PRELIMINARY RESULTS FROM THE ISAMS NO CHANNEL: THERMOSPHERIC RADIANCES

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ABSTRACT

The Improved Stratospheric and Mesospheric Sounder (ISAMS) is producing the first global measurements of emission from the 1→0 band of nitric oxide (NO). The emission from the lower thermosphere has been examined and is seen to increase dramatically at times corresponding to high solar activity. The temporal and geographical extent of the effect is reported, and possible mechanisms for the enhanced emission are discussed. The need for adequate representation of thermospheric NO emission in order to retrieve NO number densities at all heights from ISAMS data is discussed, as are prospects for science studies using such NO number density measurements.

1. INTRODUCTION

Nitric oxide (NO) is known to be produced in the Earth's thermosphere by the reaction of N atoms with O_2. Processes which produce N atoms are initiated either by absorption of solar EUV and X-rays or by precipitation of charged particles during geomagnetic disturbances at high latitudes. NO production is therefore expected to be highly correlated with solar activity. The NO so formed has been identified as a potentially important source of stratospheric NO_x (Solomon and Garcia, 1984). In this paper we report preliminary observations of radiances from the lower thermosphere in the NO channel of the Improved Stratospheric and Mesospheric Sounder (ISAMS) (Rodgers et al., this symposium)

2. PREVIOUS MEASUREMENTS OF NO IN THE THERMOSPHERE

There have been numerous observations of thermospheric NO, both by rocket-borne and space-borne sensors. Rocket measurements have mostly detected either fluorescence from the UV gamma bands (eg Barth, 1964; Thomas, 1978; Ogawa et al.,1984; Cleary, 1986) or emission from IR vibration rotation bands (eg Rawlins et al., 1981; Stair et al., 1985, Adler - Golden et al, 1991), and have been confined to high northern latitudes. Space borne instruments on platforms such as OGO 4, Atmospheric Explorer (AE) C and D, Solar Mesospheric Explorer (SME), Nimbus 7, and Space Lab 3 have detected NO by absorption in the UV delta bands (eg Massie, 1980), fluorescence in the UV gamma bands (eg Rusch and Barth, 1975; Cravens and Stewart, 1978; Cravens, 1981; Barth et al. 1988; McPeters, 1989), or absorption in the IR fundamental vibration rotation band (eg Laurent et al., 1985). Since all these measurements depend on the sun as a source of illumination, their geographical and diurnal coverage is somewhat limited. For example SME, in a sun synchronous orbit at 96° inclination, measured NO on the daylight side of the earth for at most two orbits per day.

3. ISAMS MEASUREMENTS OF NO IN THE THERMOSPHERE

ISAMS, an instrument on the Upper Atmosphere Research Satellite (UARS), has a pressure modulated gas correlation radiometer (PM) channel (see Kerridge et al.; this symposium) which measures atmospheric emission from the v=1→0 (5.3μm) transition of ground state NO. Measurements are made every 2.048 seconds as UARS orbits the Earth at 585km, along limb paths at right angles to the spacecraft velocity vector. The limb path tangent height for each 2.048 second measurement is determined by the position of a scanning mirror; this mirror is programmed to move so that tangent heights between 10km and 80km are sampled in 2.5km steps. Measurements from ISAMS (together with those from the other UARS instruments CLAES (Cryogenic Limb Array Etalon Spectrometer) and, to a more limited extent, HALOE (Halogen Occultation Experiment) therefore represent the first truly global measurements of NO throughout the middle atmosphere. A subset of ISAMS limb scans also samples heights up to >150km, principally for radiometric calibration purposes. However, in the NO channel, there is substantial emission from NO at these altitudes which is measured by ISAMS. A vertical profile of radiance in the 80 - 150km region is generated every ≈260 seconds, though this could be made more frequent by re-programming the scanning mirror movement. These profiles cover a wide range of latitudes (80S to 80N), longitudes (0 to 360E) and all local times. It must be borne in mind, however, that the radiances returned by the ISAMS NO channel are proportional to the concentration of molecules in the v=1 level along the limb path. The observations discussed here are of radiances only; inversion of the radiances to give NO (v=0) number densities has yet to be done for reasons discussed briefly below.

4. ISAMS NO RADIANCES - RELATION TO SOLAR ACTIVITY

Signals from the ISAMS NO channel are plotted daily,

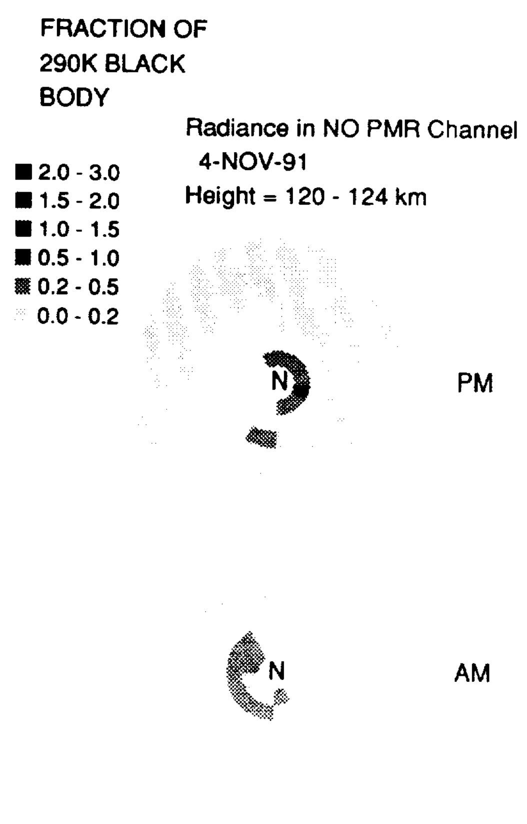

Fig. 1. NO Radiances on 4/11/91 (Northern hemisphere)

and for the most part the plots from different days look very similar. However, very unusual behaviour was observed for periods around 29/10/91, 9/11/91 and 10/5/92.

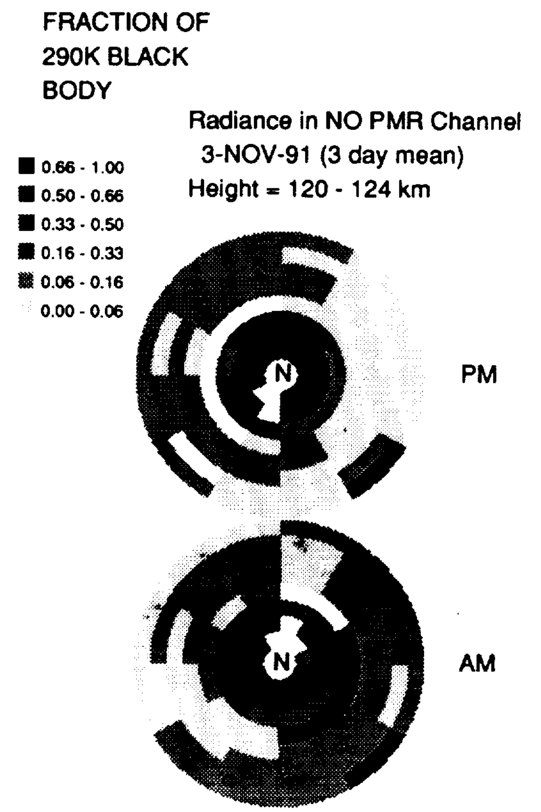

Fig. 2. NO Radiances for the period 2/11/91 to 4/11/91 inclusive (Northern hemisphere)

Vertical radiance profiles generally show a peak around 120km altitude; this peak was observed to increase dramatically at the above times. To show the geographic distribution and time evolution of NO radiance from 120km, several polar stereographic plots are presented.

Figure 1 shows a plot of NO radiance recorded by ISAMS on 4/11/91. This figure (and other similar figures in this paper) were produced by averaging data by limb path tangent point location and UT into 10° latitude bins, 30° longitude bins, 4km height bins and 12H UT bins. Latitude decreases from 90° at the center in 10° steps, while 0° longitude is at the bottom of each plot and longitude moves easterly in an anticlockwise manner. The shading of each latitude / longitude box indicates the emission from that geographical area, according to the adjacent radiance scale. One radiance unit is equivalent to that which ISAMS measures from a black body target at 290K. Unshaded boxes represent missing data, caused by the relatively infrequent sampling above 80km, which can be reduced by averaging several days together; figure 2 is an average of data from 2/11/91 to 4/11/91 inclusive. This figure shows radiances typical of relatively quiet solar conditions; ie more radiance from high latitudes than low latitudes, maximum radiances at low latitudes typically < 0.2 radiance units.

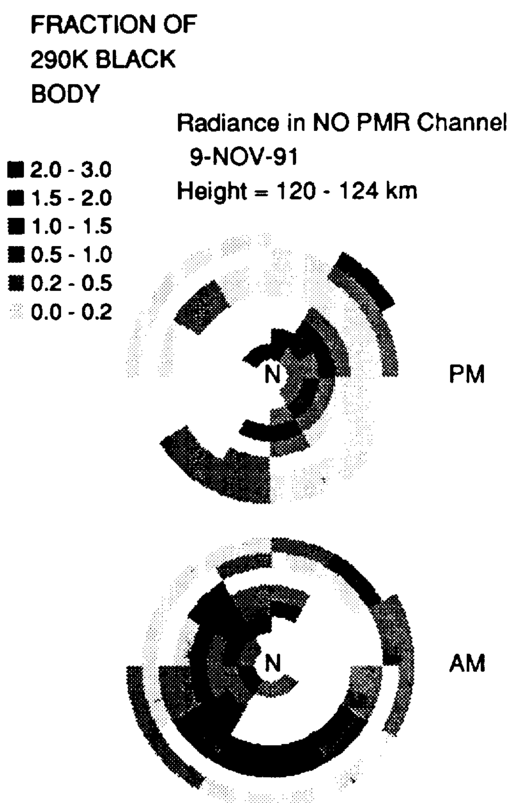

Fig. 3. NO Radiances on 9/11/91 (Northern hemisphere)

The situation on 9th November 1991 is, however, very different. Figure 3 shows the radiance maps of the northern hemisphere for this day, from which it can be seen that the NO radiance from ≈120km in some geographical locations has increased by a large factor relative to 4th November, especially in the AM UT period. The largest radiances appear to come from relatively low latitudes around 0° longitude at times when this region of the atmosphere is in darkness, and are possibly caused by compressional heating following Joule heating at higher latitudes associated with geomagnetic activity (Barth, 1992; Siskind et al. 1989a,b). In fact extensive auroral activity was reported over North America during the AM UT period of 9/11/91. The enhanced radiances may also have been caused by soft X-rays and/or EUV from the sun (Barth et al., 1988). These would have to have been incident at a previous time, since at the time ISAMS measured elevated radiances from this part of the atmosphere it was either in darkness or near dawn. Radiances from the NO channel are then observed to fall to pre-storm levels over the next few days, as shown in fig. 4, which is a 3 day mean of the period 12/11/91 to 14/11/91 inclusive.

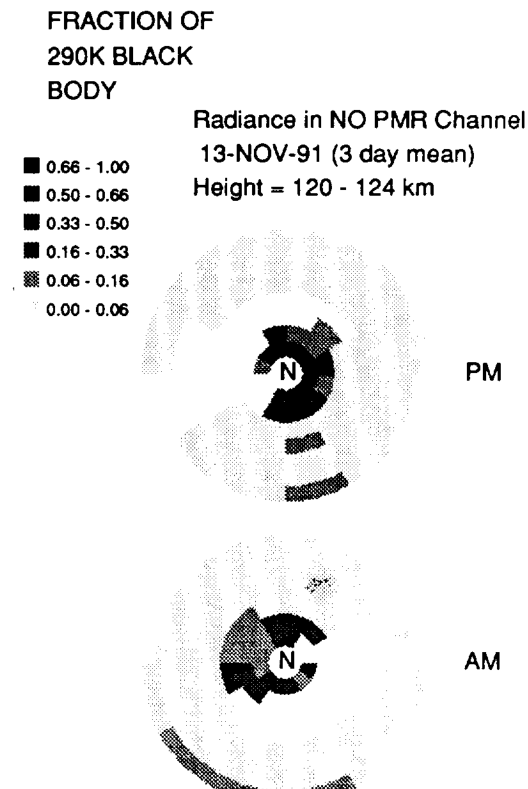

Fig. 4. NO Radiances for the period 12/11/91 to 14/11/91 inclusive (Northern hemisphere)

Radiances from the southern hemisphere show similar behaviour, though are in general lower than those from the northern; fig. 5 shows a mean of radiances for the period 2/11/91 - 4/11/91, and fig. 6 shows radiances for 9/11/91, both from the southern hemisphere.

5. PROSPECTS FOR SCIENCE STUDIES USING NUMBER DENSITY MEASUREMENTS FROM ISAMS

Inversion of measured radiances into NO (v=0) number densities is a complex process which requires, among other things, a source function for the NO emission. In regions of the atmosphere where Local Thermodynamic Equilibrium (LTE) can be assumed the source function is simply the Planck function at the atmospheric kinetic temperature. In much of the mesosphere and thermosphere, however, the 1→0 band of NO cannot be considered to be in LTE, so a more sophisticated source function is required. An appropriate source function is being generated using the MSIS (Hedin, 1983) model for temperatures, molecular densities and atomic oxygen densities, and LOWTRAN

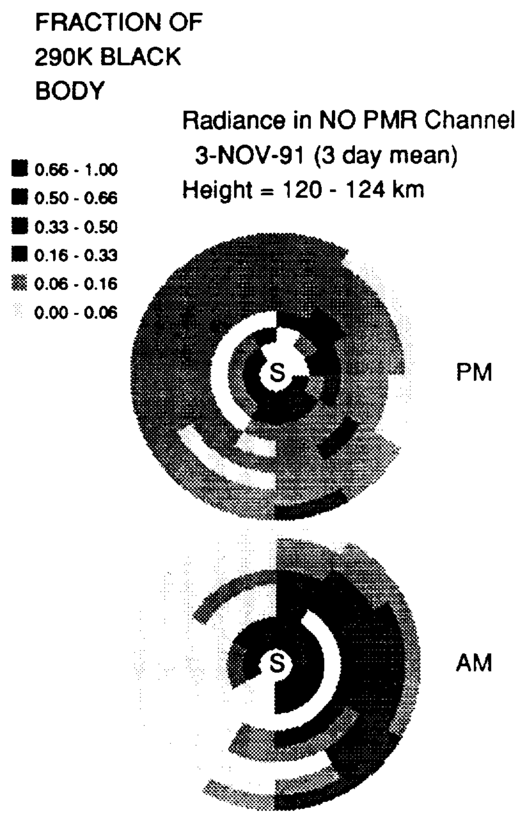

Fig. 5. NO averaged radiances on 2/11/91 to 4/11/91 inclusive (Southern hemisphere)

7 for characterising upwelling IR flux from the lower atmosphere. Further possible refinements include the use of temperatures measured by other UARS instruments, such as WINDII and HRDI.

A second difficulty concerns the radiometric calibration of the NO PMR channel, particularly the measurement of the radiometric 'zero'. ISAMS has a two-point radiometric calibration involving views to an internal black body and to space; the latter being generated by moving the limb viewing mirror to observe a high tangent altitude (>150km). There is, however, significant atmospheric emission from atmospheric NO even at these altitudes, so an appropriate radiometric 'zero' has been deduced from data acquired during a spacecraft roll manoeuvre which allowed ISAMS to view very high altitudes (> 200 km).

Several interesting science studies should be possible using thermospheric NO number densities from ISAMS, including the impact of the thermospheric NO on the stratosphere and radiative cooling of the lower thermosphere. Since the NO PM channel is predominantly sensitive to emission from the 1→0 band, whereas the corresponding wideband filter (WB) channel is sensitive to all emission in

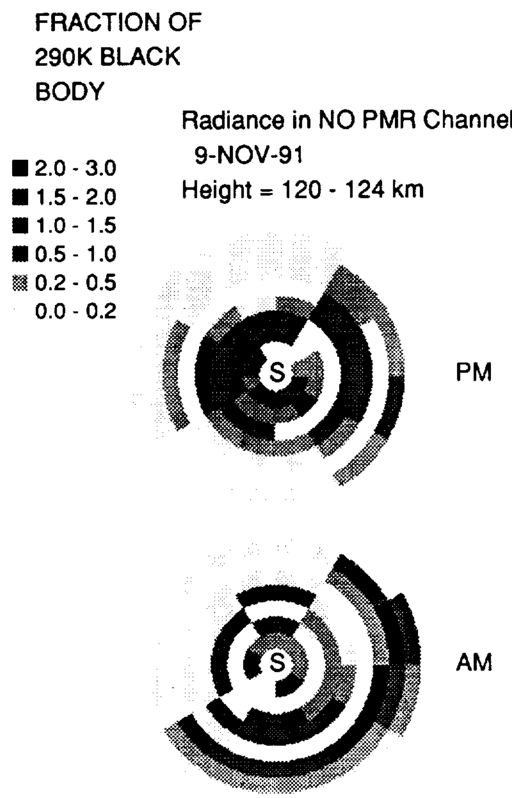

Fig. 6. NO Radiances on 9/11/91 (Southern hemisphere)

the filter passband, comparison of signals in the two channels should allow further studies of IR emission processes, such those which result in hot band emissions. It may also be possible to detect emission from NO^+ in the WB channel at 4.5μm.

Studies of the lower atmosphere will concentrate on the chemistry of NO in the stratosphere and mesosphere. Of interest in the context of the observations reported here will be studies of other atmospheric constituents, to investigate the effect of NO produced in the thermosphere on NO_x and O_3 at lower altitudes.

6. CONCLUSIONS

ISAMS is producing the first global measurements of emission from the 1 →0 band of NO. The emission from the lower thermosphere has been examined in both quiet and disturbed solar conditions; for the former the radiance from high latitudes is larger than that from low latitudes, as expected. The spatial and temporal resolution of the measurements is such that clear signatures of transient phenomena such as geomagnetic storms are seen in the NO radiances. The relatively high radiances from the thermosphere compared to those from the stratosphere mean that an adequate representation of the NO source function in the thermosphere is required for accurate retrievals of NO number densities at all levels.

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