Comparison of ISAMS NO & NO_2 with HALOE

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Introduction

The Improved Stratospheric and Mesospheric Sounder (ISAMS) is a multi-channel IR emission-sensing radiometer on NASA's Upper Atmosphere Research Satellite (UARS) which observed the distributions of temperature and trace gases including NO and NO_2 for 180 days between September 1991 and July 1992[1]. ISAMS viewed at right-angles to the UARS flight direction and scanned the atmospheric limb vertically.

UARS also carried the Halogen Occultation Experiment (HALOE), a multi-channel IR radiometer which measured profiles of temperature and trace gases, again including NO and NO_2, viewing the atmospheric limb in solar occultation[2].

The ISAMS and HALOE observations were therefore complementary. The limb-emission sounder provided extensive latitude coverage, day and night; the solar occultation instrument provided high radiometric precision, but only for a maximum of 15 sunset and 15 sunrise profiles per day in two narrow latitude bands.

Although ISAMS and HALOE viewed in different directions, ISAMS measurements on a particular day can be selected from the latitude band observed by HALOE. **Figure 1** shows the latitude extremes of ISAMS day-time and night-time coverage and the latitude sampled by HALOE at sunset for days on which data exist for both instruments (*Comparison Days*). The local time and solar zenith angle of the ISAMS data are shown at the latitudes of the HALOE observations. The correspondence between UARS Mission Day and Comparison Day is also indicated; Mission Day 1 is 12 September 1991.

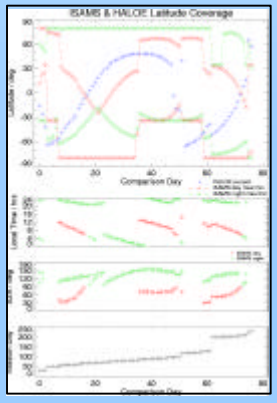

Figure 1: ISAMS and HALOE sunset observation parameters

NO and NO_2 Observations

Stratospheric NO and NO_2 are rapidly inter-converted at sunset and sunrise, i.e. during the HALOE observations. However, their sum changes only slowly during the diurnal cycle, mainly through inter-conversion with N_2O_5. The UARS data provide the first opportunity to inter-compare limb-emission and solar occultation measurements of the sum of $[NO+NO_2]$ over a large span of latitudes and times of year. Since N_2O_5 mixing ratios are a minimum at sunset, the HALOE occultations at sunset are preferred to those at sunrise.

For ISAMS, it is interesting to note that the matched night-time observations for Comparison Day ~20 were acquired close to sunrise, when a significant fraction of NO_x is in the form of N_2O_5.

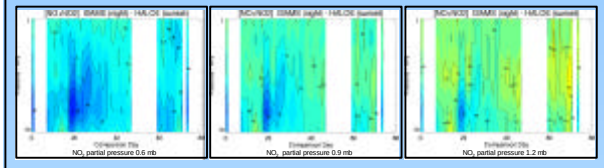

Figure 2: Daily zonal-mean difference in $[NO+NO_2]$ between ISAMS night-time and HALOE sunset. Plots are for ISAMS NO_2 cell partial pressures of 0.6, 0.9 and 1.2 mb

ISAMS Nighttime Comparison

ISAMS NO and NO_2 data have recently been reprocessed to reduce uncertainties and to remedy deficiencies identified in the existing (Version 12) data set.

For NO, handling of thermospheric emission and non-LTE source function were improved.

For NO_2, the major uncertainty was that of NO_2 partial pressure in the ISAMS pressure-modulation cell, caused by a large, unknown fraction being converted catalytically to other nitrogen oxides before launch.

The zonally-averaged difference between ISAMS night-time $[NO+NO_2]$ (effectively $[NO_2]$ since [NO] is low after sunset) and HALOE sunset $[NO+NO_2]$ is plotted in **Figure 2** for two estimates of NO_2 partial pressure derived by independent means (0.6 and 1.2mb), and also for an intermediate value (0.9mb). Due to build-up of N_2O_5 during night-time, the ISAMS - HALOE difference is expected to be negative (typically by 1-2 ppbv, but by 5-6 ppbv just before dawn). The plots indicate the 0.9mb partial pressure to yield best overall consistency.

Figure 3 compares zonally-averaged ISAMS night-time $[NO+NO_2]$ for the 0.9mb case with HALOE sunset data. Allowing for N_2O_5 production, these are consistent within their estimated errors.

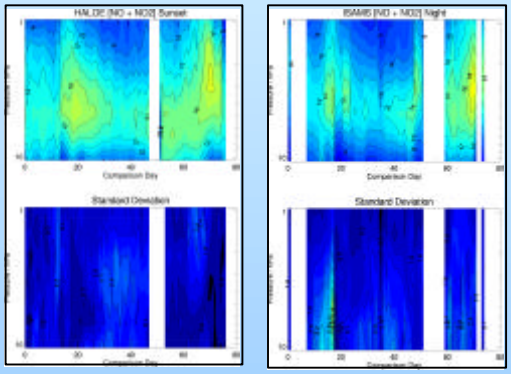

Figure 3: Daily zonal-mean HALOE sunset and ISAMS night-time $[NO+NO_2]$ volume mixing ratios (ppbv) and their standard deviations. ISAMS retrievals are for a 0.9 mb cell partial pressure and data within 2.5 deg latitude of the HALOE observations.

ISAMS Daytime Comparison

ISAMS day-time $[NO+NO_2]$ data are shown in **Figure 4** together with the *ISAMS daytime - HALOE sunset* difference. An additional complication is that the daytime emission from stratospheric NO detected by ISAMS is predicted to be enhanced by photochemical pumping[3]. The NO values used in the comparison have been corrected using the values for NO(v) quantum yield given by Kaye and Kumer[3].

Although the number of days available for comparison is smaller than for night-time, the differences between instruments are relatively small and indicate the ISAMS NO and the NO_2 data to be consistent with those from HALOE.

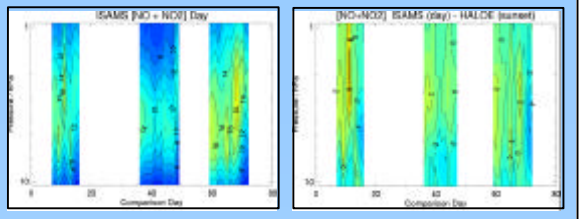

Figure 4: ISAMS day-time $[NO+NO_2]$ daily zonal mean volume mixing ratio (ppbv) and ISAMS daytime minus HALOE sunset difference. ISAMS values are for 0.9mb cell composition and data within 2.5 deg latitude of the HALOE observations are included.

Conclusions

A methodology has been demonstrated to compare satellite limb-emission and occultation measurements of NO and NO_2 which could potentially be adapted to compare MIPAS with GOMOS and/or SCIAMACHY on Envisat.

Reprocessed NO and NO_2 data from ISAMS for 1991-2 have been found to be consistent with those from HALOE, and could provide a useful reference for those from Envisat MIPAS.

The ISAMS data are more uniform and extensive than HALOE data in their latitudinal and diurnal coverage, and could therefore be more easily accommodated by chemical data assimilation models, e.g. in further studies of stratospheric global composition post-Pinatubo.

Specific findings from the ISAMS – HALOE comparison are of potential relevance to MIPAS:

- The importance of photochemical pumping to stratospheric emission from NO(v=1) has been confirmed and quantified.
- The importance of accounting for thermospheric emission in stratospheric NO retrievals has been confirmed.

Planned Further Work

- Complete the analysis of ISAMS systematic error budget.
- Systematically compare the NO/NO2 ratio retrieved from ISAMS with that predicted by a photochemical model.

Acknowledgements

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