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Stratospheric Composition from Balloon Based Measurements

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ABSTRACT

The chemical composition of the lower stratosphere has been measured using a polarizing interferometer operating in the far infrared and submillimetric spectral region.

The instrument was flown three times (in 1992, 1993 and 1994) from the NSBF balloon base (Fort Sumner, New Mexico) in coincidence with overpasses of the UARS satellite, for a total of about 50 hours of measurements.

In this paper we report some of the results obtained from the data analysis made up to now.

1. INTRODUCTION

Measurements of the composition of the earth's atmosphere is of fundamental importance for the study of atmospheric chemistry and for developing models that can predict the evolution of the atmosphere itself.

The technique of emission limb sounding, that is, measurement of the atmospheric thermal emission in the long wavelength end of the electromagnetic spectrum along different lines of sight, provides such measurements with good vertical resolution and good time coverage. It has therefore been identified as a valuable tool for many years[1].

In this paper we will discuss some results obtained from a polarizing interferometer flown on a stratospheric balloon within the framework of the UARS (Upper Atmosphere Research Satellite) intercomparison campaign.

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2. THE INSTRUMENT

The instrument was designed and built several years ago; its modular design has made it easy to upgrade it throughout its life span. In its original version it was flown several times providing a large amount of data, the analysis of which covered several years. A similar version of the instrument has also been used in laboratory measurements. A full description is beyond the scope of this paper so we will limit ourselves to listing the most important changes compared to the original version which has been described elsewhere[2,3].

1 The lead screw used to drive the moving mirror has been abandoned, and a linear motor is now used which guarantees a smoother movement; the stroke is long enough (≈ 1 m) to obtain the required resolution (≈ 0.0025 cm^{-1}). Due to the availability of faster and less noisy detectors, the scan velocity has been set to a higher value resulting in an improvement factor of ≈ 3 in data throughput.

2 A precise positioning mechanism (20 arcsec nominal accuracy for oscillations within a $\pm 3°$ range), built by the Smithsonian Astrophysical Observatory, is now being used to control the line of sight.

3 The interferogram is sampled at equal steps asyncronously with the telemetry clock; the two processes are coupled through a First In First Out buffer. The nominal acquisition rate is slightly lower than the transmission rate; so, whenever a datum has to be transmitted but no measurement is available, the old one is resent with a *repeat* flag. In a few cases, due to velocity random fluctuations one or more new data may be acquired before transmission is possible. When this happens, the data are held in a queue to wait for the next telemetry slot. When the mirror is not moving, the electronics switches to an equal-time sampling mode (this makes it possible to measure noise in the instrument).

4 A real-time monitoring of the system is now possible, thanks to improved ground support equipment which has made it possible to have instant knowledge of all instrumental parameters and a nearly real time evaluation of measured spectra, using a net connection to a remote mainframe.

5 A more efficient system for measuring the mask temperature has been designed to ensure more accurate calibration.

3. FIELD MEASUREMENTS

The instrument was flown three times: in the Spring of 1992, of 1993 and 1994; a test flight made in the Fall of 1990, provided useful engineering data but no scientific information. All flights were made as a part of an intercomparison campaign to validate UARS (Upper Atmospheric Research Satellite) data. The measurements were made within the framework of an international cooperation between

a Italian groups, Universities and CNR (National Researc Council), which provided the interferometer and part of the ground equipment;

b American groups from NASA Langley Research Center, which provided part of ground equipment, logistic support and on-board recording; support for the gondola design, construction and control were provided by the Jet Propulsion Laboratory;

c British group from Queen Mary and Westfield College, which provided the detectors and filters used during the flights.

The 1992 and 1993 flights also provided intercomparisons with the near infrared spectrometer flown by Prof. Zander, University of Liege. A somilar intercomparison had already been made some 10 years ago[4], so we obtained also a check of the long term stability of the instrument.

All the flights were made from the National Scientific Balloon Facility in Fort Sumner (New Mexico, USA), for an overall measurement time of $\approx$ 50 hours with two day to night transitions. Not all the data have the same quality: during the 1992 flight a failure in the azimuth control system caused drifts in the limb scan system that were not accounted for by the electronics, so the pointing direction had to be evaluated from scratch. In the 1993 flight a leak in the balloon caused a slow drift in float altitude and one of the detectors (broad band, see next table) showed much additional noise so it could not be used to retrieve reliable profiles. No spykes due to cosmic-rays[5] induced spykes as observed in previous flights were observed during these flights. With the exception of the 1993 flight (which ended at 22 km), all measurements were taken at a nominal altitude of 38 km (known within 100 m, using a Global Positioning System); the field of view was set so that the limiting factor for resolution was the optical path difference obtained in the instrument; the minimum tangent height was set at $\approx$ 17 km, and the vertical resolution, as defined by the field of view, was better than 3 km.

In the following table we show the spectral range covered by the two detectors used during the three flights and the approximate measurement time.

Year	Det. 1 cm^{-1}	Det. 2 cm^{-1}	Duration (hours)
1992	30-60	80-130	≈ 8
1993	40-80	≈ 49	≈ 20
1994	≈ 120	≈ 49	≈ 20

Note that, during the 1993 and 1994 flights, narrow band detectors (stressed photoconductors) were used: this implied missing some interesting molecules with no transition in the band(s), but makes background noise lower and permitted optimizing the instrument response in those bands and to measure single atmospheric constituents which have transitions in that spectral region. In our case use of narrow band detectors was aimed at the measurement of HBr , the presence of which in the stratosphere is relevant in the study of atmospheric BrO chemistry.

4. DATA ANALYSIS

To ensure accurate results two lines of data analysis were set, one in Italy and one in USA, using different algorithms to retrieve mixing ratio profiles for the different atmospheric constituents. Cross comparison of the results should ensure that no errors due to data handling are present in the final results. This choice made analysis slower but ensured a high reliability of the final products. In fact, the few discrepancies which were found while analyzing the 1992 data have been eliminated and the final profiles have been recently added to the UARS database.

We will limit ourselves here to making a few considerations on the work done by the Italian groups. It is interesting to note that the the high Signal to Noise Ratio (typically $\approx$ 800 in each spectral element) allowed accurate measurement of very small featutres but had also the side effect of making evident small intrumental errors which otherwise would have gone unnoticed.

A great deal of care went into phase correcting the data, since we found that, superimposed on the large signal from the atmosphere, there is a small residual interferogram (with a different phase) probably due to emission from the interferometer itself. This may become a problem especially during calibrations when part of the instrument emission is reflected by the mask.

The atmospheric model used in the computation was provided by radiosondes data. Spectroscopical parameters were taken from the HITRAN catalogue; the JPL catalogue was used to supplement information on small features which are not given in HITRAN.

The algorithm for evaluating atmospheric emission was written by us[6] . It has recently been compared to other algorithms, showing that it is accurate within our required specifications. The inverse problem (retrieval of mixing ratio profiles) was solved using an algorithm (global fit) specially developed by a member of our group (M. C.)[7].

Same results are given in the following figures where we show mixing ratio profiles obtained for several constituents in the 1992 and 1993 flights; for comparison we display (without error bars) also the results obtained from the BIC campaign 10 years ago. Meaning of symbols is as follows:

1 results from BIC flights : diamonds ;

2 results from 1992 flight : triangles;

3 results from 1993 flight : crosses ;

4 results from UARS satellite : solid line; two values are shown, average ± standard deviation.

5. ACKNOWLEDGEMENTS

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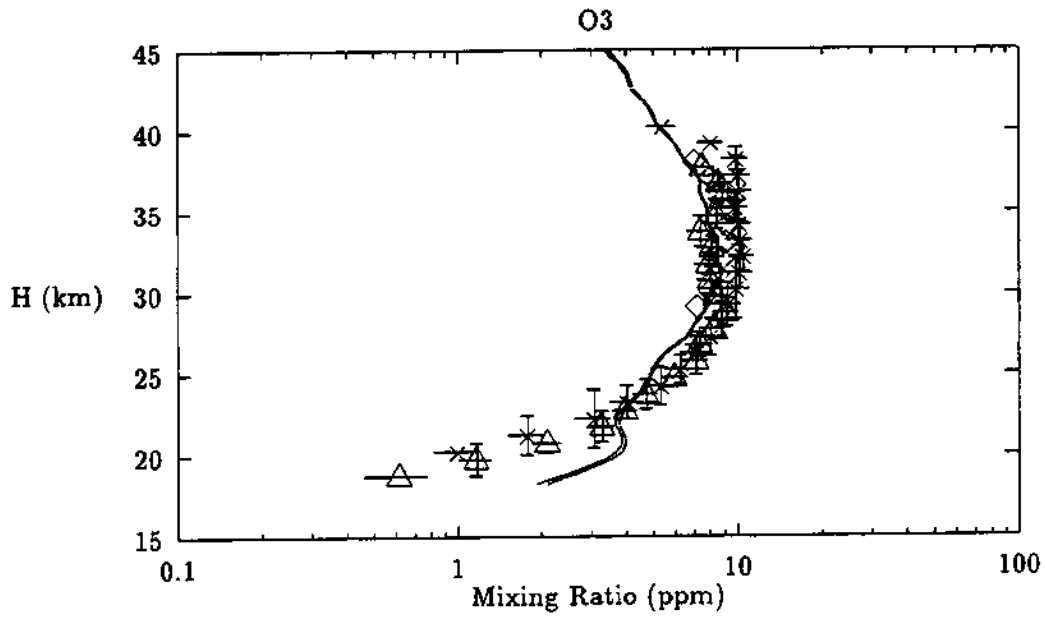

Figure 1: Vertical distribution of O_3

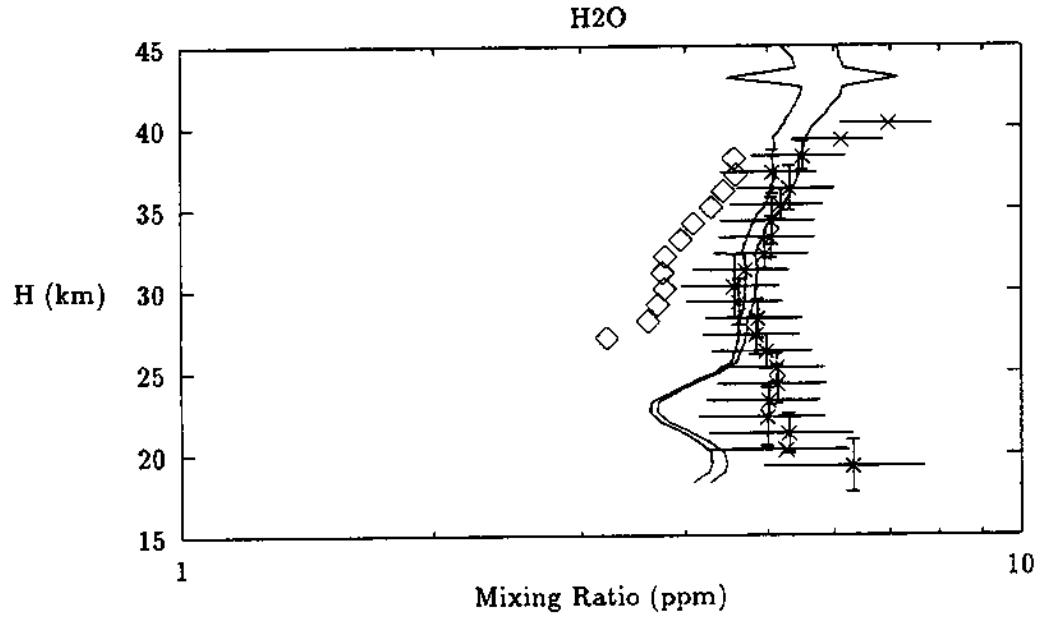

Figure 2: Vertical distribution of H_2O

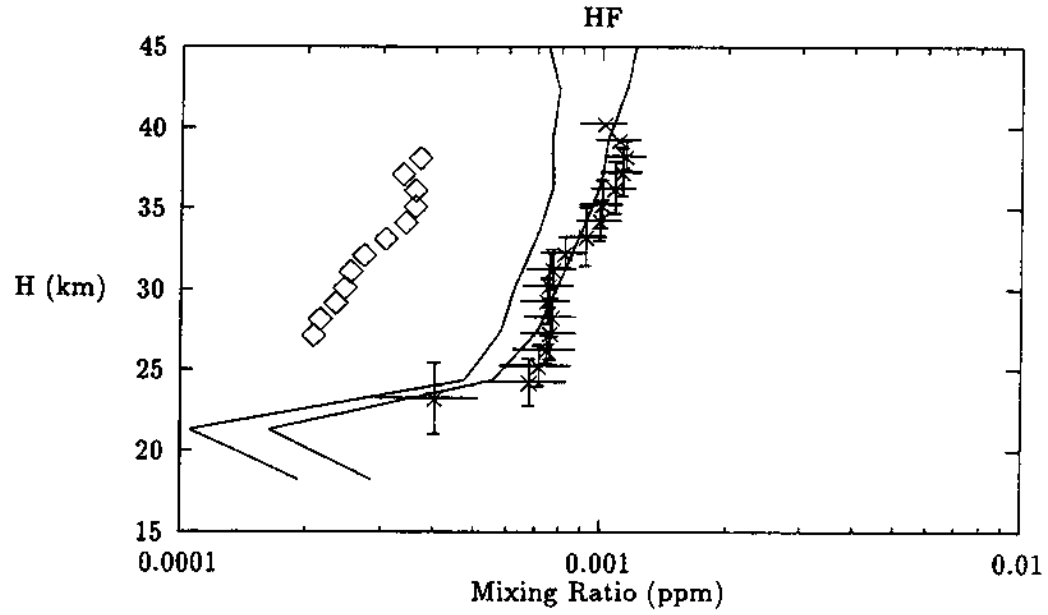

Figure 3: Vertical distribution of HF

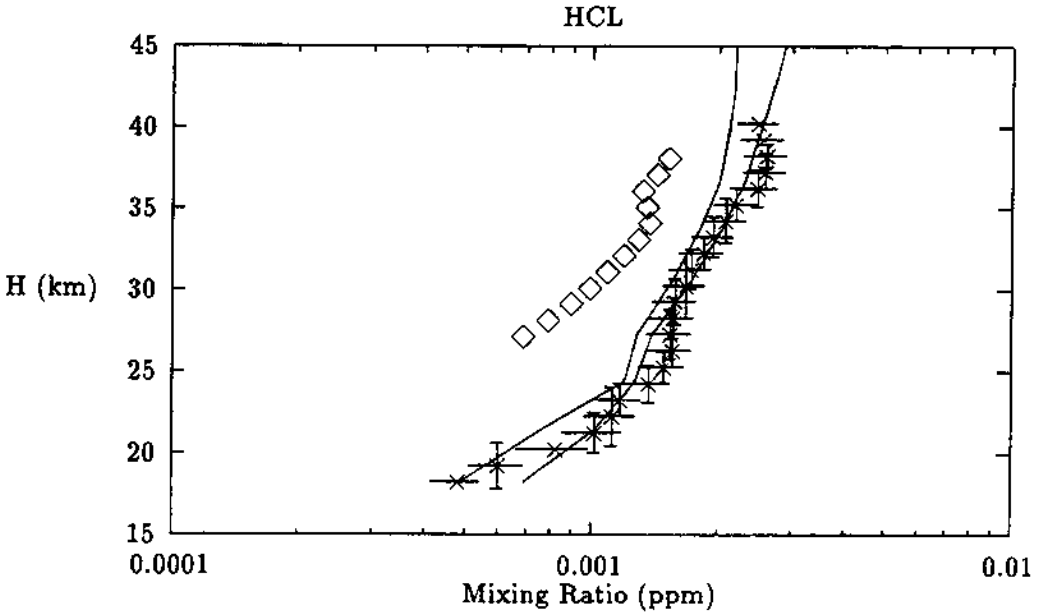

Figure 4: Vertical distribution of HCl

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