N91-71534

Position paper for Workshop on Early Detection of Stratospheric Changes

Airborne Infrared Spectroscopic Measurements

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Infrared spectroscopy is one of the most powerful methods of remote sensing of atmospheric composition. For measurements of the composition of the stratosphere, the use of a Fourier transform spectrometer on an aircraft platform provides some unique advantages, as well as some disadvantages. The advantages of Fourier transform infrared spectroscopy include the ability to achieve high resolution in a compact instrument, high signal to noise spectra due in part to the multiplex and throughput advantages, rapid recording of spectra from broad spectral regions, and a well understood instrument line shape. Since such an instrument generally records a broad spectral region, many constituents may be measured simultaneously and the spectra may be searched later for species which were not expected at the time of observation.

The principal advantage of aircraft as observing platforms is their mobility. It is possible with long range jet aircraft to reach any spot on the globe (which is politically accessible). Even a plane with comparatively short range, such as the NCAR Sabreliner, is able to cover a large geographical range with a number of flights. It is readily feasible, for instance, to cover latitude continuously from 70°N. to 55°S. This situation contrasts with the ability to launch large scientific balloons from only a few sites worldwide. Furthermore, almost any day has satisfactory conditions for an aircraft flight, whereas balloon launches may wait weeks for suitable launch and float conditions. The ability of the aircraft to go when and where observations are needed makes it very valuable for observing targets of opportunity such as volcanic eruptions or solar eclipses.

The cost of a single flight on aircraft is relatively small, so it is practical to make more flights than with balloons. This is important when looking for geographical or temporal change. Jet aircraft can reach the upper troposphere or lower stratosphere depending upon the latitude, and thus are above most of the water vapor that prevents observation from the ground at many wavelengths. Furthermore, the stratospheric column of the compound of interest is not obscured by the tropospheric contribution.

Another advantage that is frequently overlooked is the ability of the experimenter to accompany the instrument in an aircraft. This allows more complex adjustments of the instrument or observing plans during operations than is practical with a balloon experiment. Problems can be diagnosed and frequently solved. If it is necessary to cancel observations, it is usually possible to fly again in a short time period.

The chief disadvantage of aircraft as observing platforms is their inability to reach the altitudes of greatest interest for stratospheric chemistry. By observing from below the stratosphere, we can measure the total stratospheric column of many species of interest, but are not able to obtain the vertical profile in the stratosphere. Some limited height information exists in the variation of line-of-sight amount with zenith angle, or in the determination of mean pressure from pressure broadened line widths, but unless one has sufficient spectral resolution (as with microwave or laser heterodyne spectroscopy) to resolve the line shape, or uses range resolved methods (such as differential absorption lidar), one cannot obtain a true profile of stratospheric constituents from aircraft (or ground based) measurements.

Other disadvantages include the requirement of a window between the instrument and the atmosphere, and the vibration level which can cause noise problems. Solar absorption measurements are generally more sensitive for measuring trace gases, particularly in busy spectral regions, because of the higher resolution and higher signal-to-noise ratio associated with a brighter source. These have the disadvantage of being possible only near sunrise and sunset, which eliminates some very important observations such as measurements of the diurnal cycle or measurements in the polar night.

A number of groups have used infrared absorption or emission spectroscopy from aircraft for study of the stratosphere, although far fewer than have made observations from balloons. Groups that have flown spectrometers include those of Murcray at Denver University, Girard at O.N.E.R.A., and our group at NCAR. Aircraft observations have also been made in the far infrared, although there have been no such measurements recently. Girard *et al.* have made latitudinal measurements from 60° S. to 62° N. We have made a number of series of flights primarily in the Northern Hemisphere, between 1976 and 1985. Our data base contains over 12,000 individual spectra, taken from 23° S. to 72° N. in different seasons and at both sunrise and sunset. Most of the data were taken at an altitude of 12 km with solar zenith angles of 86-92°.

From this data base, we have published column amounts of NO, NO_2, HNO_3, HCl, HF, OCS, HCN, HDO, and C_2H_6. We also have data on N_2O, CH_4, O_3, H_2O, CO, and CO_2. For most of the species, we have latitudinal distributions, and seasonal, diurnal, and secular trends for some. We see, for instance, a secular trend of 4-5% per year for HCl and 12-14% per year for HF over seven years.

The perturbation of the stratospheric chemistry by the eruption of El Chichon provides an interesting example of the ability of aircraft observations to provide data on localized events. Some six months after the eruptions, the cloud of debris had extended to about 30° N., as indicated by lidar. Balloons launched at Palestine, Texas, were near the edge of the cloud. We flew under the cloud as far as 20° N. and saw several modifications to the stratospheric composition. HCl was increased, presumably due to the injection of chlorine by the volcano. NO_x was decreased. SO_2 was undetectable in the gas phase by the time of observation.