Remote sensing of the atmospheric changes and ground truth.

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A surprisingly high number of Belgian scientists have been associated with the discovery of atmospheric constituents and their measurements in the last fifty years together with a parallel school of photochemistry and modeling. These constituents include methane, nitrogen dioxide, nitrogen monoxide, hydrogen chloride,hydrogen fluoride and more recently chlorine compounds related to the sinks of man-made chemicals transported to the stratosphere.

This tradition goes on from space-platforms, balloons and ground stations in order to build a coherent picture of our current middle atmosphere, in this relatively short period of observations , variations have already been observed in the concentrations of several
atmospheric gases, the most notable being the increase of the chlorofluoro-methanes since the early seventies. Space techniques, when suitable orbits were available have shown large variations with latitude which are now in the process of being accounted for by atmospheric modeling.

The present effort will benefit considerably from a larger program extending to the whole biosphere, in order to include the soil and marine sources and sinks of these atmospheric constituents.

Historical background

The first two constituents to have been observed by teledetection , in fact solar absorption spectrometry by a Belgian were methane and nitrous oxide which were measured on low resolution infrared spectra by Professor Migeotte in 1948, in the case of CH4, this was the first observation and led to consider natural methane sources because the observed quantities could not be accounted by fossil fuel leaks, N2O had already been tentatively detected on infrared spectra by Adel ten years earlier but it can be argued that the 1948 observation was the first unambiguous one. By the time, an other Belgian , Professor Nicolet had already been investigating the photochemical aspects of these constituents in the earth 's atmosphere since about 1938, including the effects of all the nitrogen oxides: NO, NO2, N2O5, culminating in a classic paper in 1950 by introducing the hydrogen chemistry in the ozone problem (Bates and Nicolet, 1950). It was also in this time that ground-based ozone measurements were initiated at the Royal Meteorological Institute.

The next step was the measurement of a high resolution solar atlas in the middle fifties from the mountain station of the Jungfraujoch which yielded values of several minor constituents together with a solar infrared atlas developed in cooperation between the Royal Observatory and the Astrophysics Institute of the Liège University. These values compared with later observations performed at the same station with higher resolution instruments in the late seventies and eighties show an increase in methane values related to biospheric changes. This set of ground based spectra still represents for most constituents including pollution sensitive data an observation baseline against which new data must be compared.

At the same time, as secretary of the International Geophysical Year, Professor Nicolet insisted that ozone observation be conducted from the Antarctic stations, following in this way the advice of several scientists including Professor Dobson, however this requirement was followed by the Belgian Meteorological Institute only during the last campaign conducted from " Base King Baudouin " in 1966-1967 where a common team of the Dutch K.N.M.I. and the Belgian meteorological institute observed a November maximum following low October values which were however about two times higher than the minima observed twenty years after from the bases of Syowa (Japan) and Halley Bay (Great-Britain). These campaigns were unfortunately stopped after 1967 due to budgetary problems associated with the maintenance of an Antarctic station by Belgian financial means.

In parallel stratospheric balloon observations were initiated both at the newly founded Belgian Institute for Space Aeronomy by a team around Dr. M. Ackerman and at the Université de Liège by Dr. R. Zander, the stated purpose of the Brussels group was to make an inventory of stratospheric composition at Sunset and Sunrise while the Liège group was more oriented to the observation of the solar spectrum in spectral regions which cannot be observed from the ground due to tropospheric contaminants (e.g. water vapor). The Brussels group published the first identification of NO2 in a solar spectrum (Ackerman and Frimout, 1968), which, later interpreted together with spectra obtained by the Ballooning team of the Denver Research Institute yielded the first values of NO2 ever published in the stratosphere (Ackerman and Muller, 1972). This publication, proving the presence of a natural coexistence of nitrogen oxides and ozone in the stratosphere was fundamental in solving the stratospheric aircraft controversy over the ozone destruction by a catalytical chain initiated by added nitrogen oxides.

The BISA low resolution (2.5 wavenumber) limb sounding instrument was used also for CH4 determinations and was replaced in 1973 by a Girard grille spectrometer (0.1 wavenumber resolution) developed and operated together with ONERA (France) . This instrument led to the first observations of NO and HCl in the stratosphere (Ackerman et al, 1973, Ackerman et al, 1975) and to the first simultaneous measurements of NO and NO2 (Ackerman et al, 1974). These early observations show already an interesting result from the point of view of stratospheric change in the sense that successive observations of nitrogen oxides on May 13 1973 and May 14 1974, obtained both at Sunset by the same instrument and interpreted by the same techniques show a nitrogen oxide variation of about a factor of two in the middle stratosphere, proving it to be dependent on still to be defined dynamical factors.

The high resolution Liège balloon instrument was then modified in order to perform limb sounding observations and achieved in 1975 the first stratospheric HF observation, this discovery was the proof that chlorofluoromethanes reached the stratosphere and released ozone destructive chlorine compounds.

Present and future.

These successes had for effect to give the Belgo-French team of the grille spectrometer an opportunity to present a space-borne version of their instrument for inclusion in the ESA Spacelab first payload. The instrument was built and integrated in both Belgian and French industry with the constant support of a scientific team including members of ONERA (France) and BISA (Belgium). The instrument flew on November 1983 on the first Spacelab payload and retrieved data on ten upper atmospheric gases from the lower stratosphere up to the heterosphere. These constituents are: H_2O, CH_4, CO, CO_2, NO, NO_2, N_2O, O_3, HF and HCl. The obtained vertical distributions extend the range of previous balloon observations by 80 km. to the top and show significant latitudinal variations of gases in the upper mesosphere, especially in the CO and H_2O cases, these results bring new insights in the entire atmospheric chemistry and dynamics because, they could originate from transport phenomena as gravity waves developing as low as in the troposphere.

The next flight of the instrument will be in the NASA ATLAS 1 Spacelab mission now announced for September 1990 and will provide a larger number of occultations ,an emission mode designed for the observation of thermospheric emissions will also be tested during this flight.

The only comparable or better limb sounding instrument to have been flown is the NASA ATMOS high resolution interferometer which flew on Spacelab 3 in May of 1985 and which is scheduled to fly together with the grille spectrometer on the ATLAS 1 mission, and will be later scheduled by NASA to fly on all the ATLAS series flights. This higher resolution is relevant also to the Belgian program in reason of the implication of Dr. R. Zander of the Liège University as a co-investigator for data interpretation. His publications with the ATMOS group include complete balances of chlorine and nitrogen species including the detections of carbonyl fluoride, chlorine nitrate and HO_2NO_2. The Liège group also continues a ground based spectral survey from the ground using a high resolution infrared interferometer, which has provided unique data on the hydrogen fluoride growth in the stratosphere, and by comparison with the spectra measured at the same place thirty years later permits to deduce the growth of atmospheric methane.

Future projects.

An already well developed radiometer is scheduled to fly on the first Eureca payload in 1991, it combines an Oxford designed PMR radiometer with filter channels and is built and integrated at the Belgian Institute for Space Aeronomy, this instrument will operate in occultation and measure essentially ozone, water vapor and aerosols on a global basis.

The other projects are now in the proposal phase and will mostly use the new ESA projects for the polar and coorbiting platforms from the Colombus-Space-station system. They are all characterized by improvements in detector performance which either permit greater detectivities or, if arrays are used spectral imaging properties. Proposals with Belgian participation now exist in the U.V, visible, infrared and microwave and aim at the establishment of a data base of atmospheric evolution.

These space projects will be supplemented by continued participation in balloon and mountain station observation.

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The total amount of publications in these subjects certainly exceeds the allocated 6 pages for this text. I will simply indicate the more recent space experiments: the Spacelab grille spectrometer and Atmos interferometer.

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