The middle atmosphere in IAMAS – 30 years ago

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In the eighties IAMAS (International Association of Meteorology and Atmospheric Science) and ICMA (International Commission on the Middle Atmosphere of IAMAS) still used to be IAMAP (International Association of Meteorology and Atmospheric Physics) and ICMUA (International Commission on the Meteorology of the Upper Atmosphere), respectively. The change of names is reflecting the broadening and a change of understanding of the research fields represented by the association and the commission due to significant progress of atmospheric science in that decade. IAMAS wanted to give more weight to atmospheric chemistry playing an increasingly important role, whereas ICMUA adjusted its name to the focus of its major activities, namely the middle atmosphere. When the commission was established with R. G. Murgatroyd as chairperson and still in the beginning of the eighties, the region which is now termed middle atmosphere was often addressed as "ignorosphere". It may therefore be appropriate to review briefly the state of middle atmosphere research around 1980.

First discussions of an international program for stratosphere, mesosphere and lower ionosphere research (Structure and Energetics of the Stratosphere and Mesosphere, SESAME) under SCOSTEP (Scientific Committee on Solar-Terrestrial Physics) started during the 70ies in the relevant commissions of IAMAP and divisions of IAGA. It became the Middle Atmosphere Program (MAP) and lasted from 1982 till 1985. Towards its end intensive planning of the ambitious follow-up program STEP (Solar-Terrestrial Energy Program) started. ICMUA actively participated in its preparation. Since STEP could only commence in 1990, the gap between both programs was bridged by the Middle Atmosphere Program Continuation (MAC) in order to keep advanced activities in middle atmosphere research going.

Regarding the state of experimental and theoretical work, availability of computational resources and the quality, type and coverage of data, it was still Stone Age when compared to the present situation. This does not mean that middle atmosphere researchers were less smart, ambitious and imaginative than they are now. Yet they had to live with the scientific and financial means available at their time (as they have to do now) paving the way from the ignorosphere to advanced understanding of the middle atmosphere. Satellite experiments designed for middle atmosphere observations gradually improved, starting with temperature and total ozone measurements and moving to observations of vertical ozone profiles and other important trace gases. Prominent satellites at that time were Nimbus-7 (1978 – 1983) with four relevant experiments on board (LIMS, SBUV, TOMS, SAMS) and the Solar Mesosphere Explorer (SME, 1981 – 1989). The Limb Infrared Monitor of the Stratosphere (LIMS) was mapping the vertical profiles of temperature and the concentration of ozone, water vapor, nitrogen dioxide, and nitric acid. The height range was 10 to 65 km for temperature and ozone and 10 to 50 km for the other trace gases. The the Solar Backscatter Ultraviolet and Total Ozone Mapping Spectrometer (SBUV/TOMS) determined the vertical distribution of ozone, contributed to the global mapping of total ozone and monitored the incident solar ultraviolet (UV) irradiance and infrared radiation backscattered from the earth. The Stratospheric and Mesospheric Sounder (SAMS) was designed to observe emission from the limb of the atmosphere in order to determine temperature and vertical concentrations of H_2O, N_2O, CH_4, CO and NO in the stratosphere and mesosphere. Zonal wind in this region was derived from the Doppler shift of atmospheric emission lines. The objective of the Solar Mesosphere

Explorer was to investigate the processes that create and destroy the ozone in Earth's upper atmosphere, or mesosphere. It monitored infrared and solar ultraviolet radiation and visible nitrogen dioxide. Evidently this was pre-UARS (Upper Atmosphere Research Satellite) time with much more sophisticated experiments (Fig. 1).

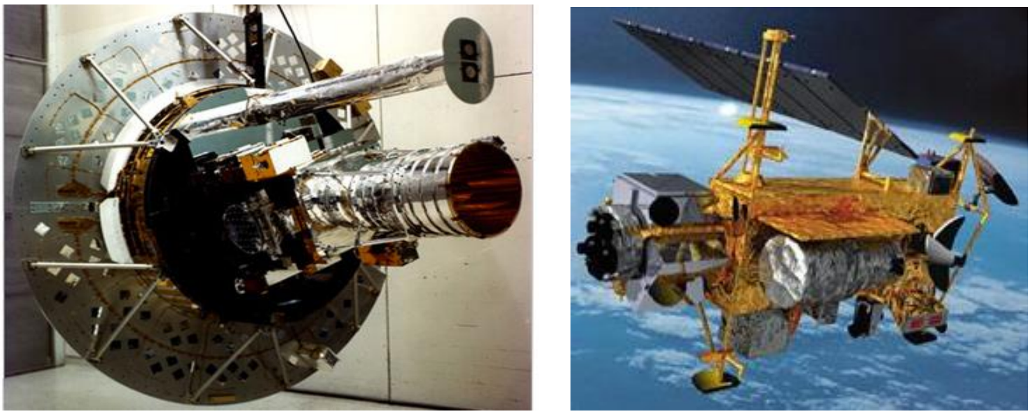

Figure 1: Two satellites which played a crucial role for middle atmosphere research – Solar Mesosphere Explorer (SME), October 1981 – October 89, left panel, and Upper Atmosphere Research Satellite (UARS), under construction since 1979, operational September 1991 till December 2005, right panel.

The fact that the satellites missed to detect the ozone hole over Antarctica is pointing to the importance of ground-based and in-situ observations of the middle atmosphere. First indications of extreme ozone destruction over the South Pole were actually found 1984 by balloon ozone sondes. First empirical models of the middle atmosphere temperature and circulation were based on balloon, rocket, lidar, LF, MF, VHF and meteor radar observations revealing the well known, but initially unexplained wind reversal with height, which appeared to be particularly pronounced in the summer hemisphere. Analyzing the energy and momentum balance of such models it was shown that they would require strong vertical winds of the order of several centimeters per second. This meant serious provocation of theoreticians dealing with stratospheric circulation and being used to some millimeters per second. Again carefully conducted measurements, in this case by MST radars, solved the problem in favor of stronger vertical motions, and theory quickly adjusted by postulating specific heat sources at upper mesosphere levels.

Figure 2: Middle and Upper Atmosphere (MU) radar of the University of Kyoto at Shigaraki, Japan, operating at 46.5 MHz. Constructed 1984.

A rather realistic picture of the global climatology and large scale dynamical features, e.g. annual, semiannual (SAO) and quasi-biennial oscillations (QBO), planetary and tidal waves and stratospheric warmings was emerging. Yet the atmospheric behavior at very high and equatorial latitudes, mechanisms of the forcing of the middle atmosphere from below and above, the formation of the D-region winter anomaly and transport of heat, momentum und matter – the latter with regard to chemistry, trace gas distribution and exchange of air at the lower and upper boundary of the middle atmosphere – were among those issues which still needed deeper and more intensive research. The peculiar temporal and spatial behavior of the mesopause was a focus of much experimental work and waited for explanation.

A dramatic step forward of middle atmosphere research occurred after Lindzen had published his ground-breaking paper on "Turbulence and stress owing to gravity wave and tidal wave breakdown" in 1981. It enabled new and consistent interpretation of strong irregular wind perturbations at mesopause heights and resulted in more realistic modeling of mesospheric circulation through the introduction of physically reasonable parameters for momentum deposition controlled by lower level circulation. An early example of modeled zonal wind distribution without and with inclusion of gravity wave drag using Lindzen's formulation is shown in Fig. 3.

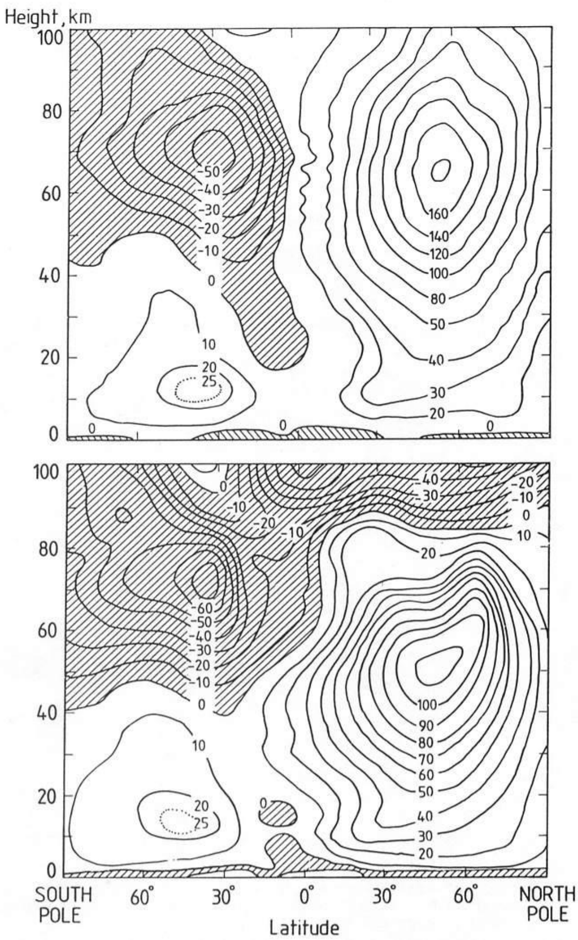

Figure 3: Time averaged wind distribution for models excluding (upper panel) and including wave drag following Lindzen's – 1981 – formulation. Areas with east winds are hatched. Units in m/s. From B. G. Hunt, Middle atmosphere response to solar and tropospheric forcing; SCOSTEP symposium "STEP – Major Scientific Problems", Espoo, Finland, 1988, referring to J. Meteorol. Soc. Japan, 64, 1 – 16, 1986

First general circulation models incorporating the middle atmosphere partly or totally appeared on the scene though the majority of numerical meteorological modelers still believed that it would be sufficient to extend global and regional models only to the lowest or middle stratosphere. On the other hand, the majority of middle atmosphere models were mechanistic ones excluding the troposphere and covering selected parts of the stratosphere and/or mesosphere with the lowest thermosphere. They have been designed to study special dynamical phenomena and processes like stratospheric warmings, the QBO, planetary waves, tides, turbulence, gravity wave impacts and solar activity effects. They proved to be powerful tools for the advancement of the understanding of middle atmosphere dynamics and - later on - also chemistry. Their advantage was that they could well be adjusted to at that time quite limited computational resources. Supercomputer performance increased since 1980 by seven orders of magnitude from about 10^9 to 10^{16} FLOPS.

Communication was appreciably slower than nowadays. Telephone, telex and fax used to be the fastest ways for message and data exchange. Commercial internet providers and the World Wide Web only became available at the late 80ies and early 90ies. This, of course, appreciably shaped the style and efficiency of the work of the international associations and its commissions, divisions, working groups, panels etc. A peculiar feature of communication and cooperation at that time originated from the existence of the iron curtain between East and West as a sometimes insurmountable obstacle. Feeling the obligation and responsibility that science has to overcome such barriers wherever they are erected a lot of the activity of scientific organizations was devoted to this task before the fall of the wall. This was also true for ICMUA trying to involve colleagues from eastern countries in its activities as closely as possible. Most of the sparse financial resources of the commission were used to enable their participation in conferences and workshops organized or sponsored by it in the west.

The middle/upper atmosphere commission noticing the quick growth of knowledge through intensified experimental activities, theoretical progress and increasing computational capacity in its field adjusted to the situation after intensive and seminal discussions during then IUGG assembly at Canberra 1979. Before it regarded the organization of biennial middle atmosphere sessions at IAMAP and IUGG assemblies as its main task. From now on it also aimed at the extension of its activities through working groups dealing with central topics of middle and upper atmosphere research. The commission president (Roper) and secretary (Ebel) had in a certain sense diverging research interests directed to upper and lower atmospheric levels, respectively, with the focus on experimental work on the one hand and on statistical and simulation studies on the other hand. This helped to strengthen the ties upward with IAGA's lower ionosphere and thermosphere division and downward with the relevant sister commissions in IAMAP dealing with ozone, radiation and dynamical meteorology.

At Canberra ICMUA's dormant Working Group (WG) on Noctilucent Clouds (chair O. Avaste, Estonia; later joined by G. Thomas, USA) was reactivated. In the following months two additional WGs were launched: WG on Tides in the Mesosphere and Lower Thermosphere (chair J. M. Forbes, USA) and WG on Solar-Terrestrial Relationships (co-chairs A. D. Belmont, USA, A. Ebel, FRG). The WG on Climatology of the Middle Atmosphere was approved in 1982 (chair K. Labitzke, succeeded by S. Kato 1987). Finally the commission established a fifth WG on Modeling of the Middle Atmosphere (chair A. Ebel) which was proposed at its business meeting in Prague 1985 and approved during the IUGG Assembly in Vancouver 1987. General objectives of the working groups were to stimulate support of commission activities by competent researchers who could not directly join ICMUA as members due to the restrictive rules of membership of the scientific associations. Furthermore the WG members were usually involved in the work of other international scientific bodies under the umbrella of ICSU (International Commission of Scientific Unions) thus intensifying the exchange of information and ideas for the benefit of

ICMUA and IAMAP at the end. The WGs soon became a basis for the generation and execution of specific studies of the middle atmosphere alone or in cooperation with other groups from other international commissions, associations or programs. The success of ICMUA's WG policy has been demonstrated by a large number of attractive sessions and workshops at IUGG, IAMAP and IAGA assemblies and contributions to international meetings arranged by other scientific organizations. In many cases the WGs were more successful than the commission itself to get over the political obstacles which existed at that time between East and West. A prominent example was the WG on Noctilucent Clouds with its Estonian chairman, O. Avaste. He succeeded to arrange several well attended workshops in Tallin in cooperation with IAGA, thereby stimulating peaceful discussions between scientists from both sides in less peaceful times. This aspect of exchange between the political blocks became especially important after the start of "Glasnost" followed by the collapse of the Soviet Union.

ICMUA was anxious to intensify cooperation with all organizations which have been active in middle atmosphere research and participated in their projects and programs in many ways either through personal involvement of its commission and WG members or through administrative and management support in many cases. Of course, ICMUA considerably gained from this involvement. Especially to be mentioned are the Committee on Space Research (COSPAR), the International Union of Radio Science (URSI) and the Scientific Committee on Solar-Terrestrial Physics (SCOSTEP). Traditionally, IAMAP has been represented by a member of ICMUA on the SCOSTEP Bureau and could thus directly shape the Solar-Terrestrial Energy Program (STEP), which was planned during the 80ies as the central project of SCOSTEP for the 90ies, according to its needs and views regarding middle atmosphere research.

Symposia and sessions on middle atmosphere physics organized by ICMUA during the IUGG and IAMAP assemblies gradually became broader regarding the topics treated by them with growing attendance. A first highlight was the Middle Atmosphere Science Symposium (MASS) jointly organized by IAMAP (lead commission ICMUA) and IAGA (lead Division II, Aeronomic Phenomena) during the IUGG Assembly in Hamburg, FRG, 1983. Considering the strong overlap of the regions of interest of both associations the commission decided with agreement of the IAMAP Executive Committee to meet during the individual IAMAP and IAGA assemblies alternatively every fourth year. Main contributions to MASS appeared in a special issue of the Journal of Atmospheric and Terrestrial Physics (JATP, now JASTP). ICMUA supported MAP at the same assembly by organizing a symposium on first results of the program and publishing another special issue of JATP with a selection of papers presented there.

This report mainly covers the two terms of the ICMUA President (R. G. Roper) and Secretary (A. Ebel) elected 1979 in Canberra. At the IUGG Assembly in Vancouver 1987 R. A. Vincent and G. E. Thomas were elected to lead the commission to new frontiers at a time when MAP/MAC faded out, STEP started to illuminate middle atmosphere research with first bright rays and UARS was finally launched.