Abstract

The internationally coordinated MAP (Middle Atmosphere Program) is an attempt to obtain the scientific knowledge which is required for answering the important questions :

(1) What are the possibilities of damage to the earth's middle atmosphere as a result of mankind's activities such as the permanent reduction of the ozone concentration in the stratosphere ?

(2). What role does the middle atmosphere play in determining climate and climatic changes?

The MAP in Japan consists of five projects : (1) Winds and waves (2) Constituents (3) Aerosols and radiation (4) Coordinated observatons in Antarctica (5) Data analysis and modelling.

The Meteorological Research Institute participated in the projects (2), (3) and (5).

(a) Constituents

Ozone and ozone-related constituents such as CF_2Cl_2 , $CFCl_3$, N_2O , CH_4 , were observed to understand the structure and behavior of the ozone layer. Various techniques, such as the electrochemical ozonesonde, chemical analysis of sampled air, and absorption spectroscopy, were used. The results are described in Chapter 1 through Chapter 5 .

In Chap. 1 the measurement of CF_2Cl_2 , $CFCl_3$, and N_2O by GC-ECD is described. Air samples have been collected over Japan and analyzed for CF_2Cl_2 , $CFCl_3$ and N_2O by a GC-ECD method since 1978. Mean tropospheric volume mixing ratios of CF_2Cl_2 and $CFCl_3$ have increased by 4 - 6 % yr^{-1} in the last few years. That of N_2O was almost constant in the same period. They were 361 ppt for CF_2Cl_2 , 218 ppt for $CFCl_3$ and 303 ppb for N_2O between December 1984 and January 1985. The mixing ratios of CF_2Cl_2 , $CFCl_3$ and N_2O in the stratosphere decreased with increasing altitude in accordance with our 1 - D photochemical - diffusive model. No tendency of CF_2Cl_2 and $CFCl_3$ to increase in the stratosphere could be detected.

In Chap. 2 the observation of ozone by the ozonesonde is described. The vertical profiles of atmospheric ozone , temperature and wind up to about 3 mb level were obtained by the electrochemical ozonesondes with 5 kg balloon.

An aneroid barometer (RS 2 - 80) was used to measure ambient pressure. The meas - urement error at 3 mb was estimated to be about 0.23 mb, corresponding to about 550m in altitude. The pump system is the same type as used in the KC - 79 ozonesonde, with some improvement to assure that the bubbling of the air stops below 2 mb.

Ozonesondes were launched in the winter season during February 1983 through December 1985. At 4 mb level (about 37.5 km) ozone concentration decreased with temperature and increased with westerly wind speed. The ozone above 10 mb level showed low concentration in the winter of 1982 - 1983, which suggests some relation with the eruption of E1 Chichon.

In Chap. 3 the measurement of minor constituents by absorption spectroscopy is described. The sunset infrared solar spectra were obtained by aircraft and total column abundances and mixing ratios of N_2O, CH_4, $CFCl_3$ and CF_2Cl_2 in the winter season were estimated.

The volume mixing ratios of N_2O in the troposphere in 1984 were 0.292 ppm (12 Dec) and 0.310 ppm (13 Dec), which were very close to the value 0.303 ppm obtained in the same winter by gas - chromatographic method, while the mixing ratio in lower stratosphere - up - per troposphere obtained in February 1984 was about 0.425 ppm. CH_4 in the upper tropo - sphere showed a very high mixing ratio (above 2.2 ppm) compared with 1.74 ppm in the lower troposphere obtained by gas - chromatographic method. Those of CF_2Cl_2 and $CFCl_3$ were 301 and 196 ppt, respectively at the level of the tropopause, and 365 and 200 ppt, respectively in the upper troposphere.

In Chap. 4 the ion - pair production rate in the stratosphere is described. The ion - pair production rates in the stratosphere were observed by using three Al - ionization chambers with different wall thicknesses (i. e. 0.4, 0.8 and 3.0 mm) and the same volume, loaded in the large balloon launched from the Sanriku Balloon Observatory, ISAS, on May 25, 1984.

(1) Pfotzer Maximum was observed at 17 - 18 km height. (2) There were no significant differences among the values of ion production rates in the free air observed by three cham- bers, above Pfotzer Maximum, while (3) slight differences were found below Pfotzer Maxi - mum, especially at 4 - 15 km height. (4) It was found that the value of the ion-pair pro - duction rate at Pfotzer Maximum in 1984 was large by about 1 % than in 1982. (5) Our val - ues of ion-pair production rates in the stratosphere are plotted, compared with those by Bra - sseur and Nicolet (1973).

(b) Aerosols and radiation

To understand the possible role of aerosols on radiation, integrated aerosol - radiation experiments were carried out. Aerosols in the stratosphere and the troposphere were observed by use of a lidar system and an aircraft. Measurements of downward and upward fluxes of solar and infrared radiation were made by a balloon - borne sonde and an aircraft. The effect of aerosols on the radiative heat budget was evaluated. The results are described in Chapter 5 through Chapter 8.

In Chap. 5 ground - based lidar monitoring of stratospheric aerosol is described. Large amounts of dust particles were injected into the stratosphere by the volcanic eruption of El Chichon in late March and early April 1982. The ruby lidar (wavelength 694.3 nm) at the Meteorological Research Institute detected an increase of dust particles.

Backscattering ratio (R), backscattering coefficients (β_A) and integrated β_A over a height range of 16.5 - 30.5 km (B) are shown in the tables, and the time variation of B in the figure. After the eruption, two enhancements of B appeared — in May and in December 1982. The value of B decreased gradually with a time constant of about 7 months during December 1982 through September 1983. No seasonal variation of the stratospheric aerosols was clear as yet.

R or β_A was estimated as follows. The backscattering coefficient of atmospheric molecules was calculated by $\beta_M = n \times 1.771 \times 10^{-27}$ cm^{-1} sr^{-1}, n is the density of atmospheric molecules obtained from daily rawinsonde at Tateno near the lidar site and average data of meteorological rocket sondes at Ryori (39° 03′ N, 141° 50′ E). A weighted mean method was used to calculate R, β_A and their standard deviation (Russel et al., 1979). The ratio of aerosol extinction to aerosol backscatter was assumed to be 50 steradians.

In Chap. 6 observation of the fluxes of solar radiation by solar radiation sonde is described. The structure and calibration of our solar radiation sonde are briefly described. Unlike the radiometer sonde, the swing of the solar radiation sonde affects largely on the measurement of downward solar radiation. The method of eliminating or minimizing the effect of the swing is described.

Then the observation results on the altitude distribution of both upward and downward solar radiation fluxes on several days under a clear sky are shown. The observation shows the upward (reflective) solar radiation flux is clearly affected by the reflective property of the ground surface and that the atmosphere is heated by solar radiation as expected by theoretical estimation.

In Chap. 7 observation of the fluxes of infrared radiation by radiometer sonde is described. The structure of our radiometer sonde is briefly described and the calibration of the radiometer sonde, especially the effect of wind speed (air flux) on the instrument constants of the sonde is described on the basis of the exeriments.

Then the results of obsevation of the altitude distribution of both upward and downward infrared radiative fluxes on several days under a clear sky are shown. The infrared radiative net fluxes (upward flux minus downward flux) observed cause atmospheric heating in layers above 100 mb level, while those computed using the altitude distribution of temperature and humidity obtained by radiosonde within three hours after each observation of radiative flux cause atmospheric cooling in the same layer as usual.

In Chap. 8 simultaneous measurement of aerosols and solar and infrared radiation by aircraft is described. A series of aircraft observations was carried out for this purpose over Tsukuba (land) and Kashimanada (sea) in three winter seasons.

Effects of tropospheric aerosols on the solar and infrared radiative heat budget were evaluated. In the lower troposphere the solar heating rate due to absorption by aerosols is about twice as large as that due to water vapor. In a dense haze the infrared radiative cooling rate tends to be smaller, with an intensified cooling rate near the top of the layer. The vertical profile of radiative heating and cooling rates well corresponds to the vertical distribution of aerosols, which is, in turn, closely related to the atmospheric profiles such as temperature inversion and mixing layer.

(c) Data analysis and numerical modelling

Global data analysis was made to understand the coupling between the upper and the lower atmosphere. Special attention was focused on the relation between the day-to-day change of geomagnetic Sq fields due to ionospheric wind variations and the vertical energy propagation. The relationship between the climatic variation and the geomagnetic variation was also studied by statistical method. For the understanding of the physical processes in the middle atmosphere numerical models were constructed without any parameterization for small-scale motions such as internal gravity wave and dry convections, and the role of these motions was studied. The results are described in Chapters 9 and 10.

In Chap. 9 the relationship between middle atmosphere disturbances and geomagnetic variations have been studied using various data, such as geomagnetic variations, geomagnetic activity indices, ionospheric variations, aerological data, surface meteorological data and sunspot numbers. Various relationships are suggested from the observational results of the present study.

It is clarified that the focus of Sq currents varies day by day with a period of several to several ten days. It is also suggested that the variation of the Sq focus is related to the planetary wave. Secondly, it is clarified that QBO is also seen in the geomagnetic variations. However, the physical relationship between the geomagnetic QBO and the meteorological QBO is reserved for future study. The relationship between the climatic variation and the geomagnetic variation is also examined in the present study.

The influence of geomagnetic disturbances on the tropospheric circulation has been investigated for five winter seasons (1976 - 1981) using superposed epoch analysis.

It was found that changes in planetary wave activity occur in middle and high latitudes after geomagnetic disturbances. Significant increase of weather forecast errors near the trough regions are also found one day after geomagnetic disturbances.

In Chap. 10 the general circulation of the middle atmosphere is simulated by means of a two - dimensional and a three - dimensional primitive equation models. The models are capable of explicitly representing internal gravity waves of zonal wavelength greater than a few hundred kilometers (in a three - dimensional model). No parameterization is employed for subgrid - scale eddy viscosity.

With the assumption of a simple external - heating function corresponding to solstice conditions , time integration was performed. During the whole period, random forcings were imposed on each grid of the lowest level in order to generate small - scale upward propagating internal gravity waves.

Experiments have shown that small - scale waves were indeed excited, propagating upward, broke up near the mesopause, and greatly changed the thermally induced zonal mean motion and temperature fields in the upper mesosphere and the lower thermosphere. As a result, important features of the general circulation at that level, such as reversals of the zonal motion and the latitudinal gradient of zonal mean temperature, were reproduced.

In Appendix some of the observations in Antarctica concerning minor constituents are described. Ozone observations were carried out at Syowa Station, Antarctica (69° 00′ S, 39° 35′ E) from February 1982 to January 1983. The observation items were total ozone amount, vertical distribution by ozonesonde and Umkehr observations, and surface ozone mixing ratio. Many interesting characteristics have emerged from these results, such as the total ozone maximum in winter.

Columnar amounts of atmospheric minor constituents such as N_2O, CH_4, $CFCl_3$, CF_2Cl_2 and HNO_3 were determined from the infrared solar spectra for the period 24 March 1983 - 29 December 1984 at Syowa Station, Antarctica. Total atmospheric nitrous oxide (N_2O) deduced from the transmittance of solar radiation st 2576 cm^{-1} (3.88 μm) indicated seasonal variation with two maxima - in spring and autumn. The volume mixing ratio of tropospheric N_2O was close to 300 ppb.

At Syowa Station, volume mixing ratios CF_2Cl_2 and $CFCl_3$ increased by 5 - 6 % yr^{-1} between February 1982 and December 1984. Those at Syowa Station were 3 - 4 % lower for CF_2Cl_2 and 5 - 7 % lower for $CFCl_3$ than those observed over Japan in the same period. These increasing rates and differences between the southern and northern hemispheres were both smaller than those observed in the 1970′ s. Volume mixing ratio of N_2O was almost constant in the same period, and no difference was found between the southern and northern hemispheres.