SYNOPSIS

The present project consists of three parts: (a) observation of the meteorological field with local circulations under complex terrain, (b) observation of medium-range transport of air pollutants and (c) numerical simulation of local circulation and transport of air pollutants in it.

The studies were performed for the three fiscal years 1980 to '82. The observations (a) and (b) were made in the central part of the Inland Sea and its coastal regions during 22–24 July 1980, 18–20 August 1981 and 27–30 July 1982.

We describe our experiment in the following for each year. The preliminary experiment was done in the year 1980. Hourly pilot balloon observation was made at three sites to reveal the general flow and the characteristic features of local circulation. A Doppler sodar installed at Niihama reinforced the observations, and gave some information about turbulence aloft. Radiosonde observation in the lower atmosphere was also made at Niihama and provided vertical temperature distribution.

Aircraft mesurments were made of NO, NO_X and O_3 concentrations, air temperature, dew point temperature, ground surface temperature. The mesurement aimed at tracking pollutants emitted by large stacks in the Niihama area, which were transported both by the general wind and the complex local winds.

A multiple air tracer technique applicable to the range of 10 to 100 Km was developed, and field experiments of the technique were conducted at Niihama. In those experiments, two different chemical compounds, Dysprosium and Europium, were used for tracer materials, which were released in the sea-breeze and land-breeze flows respectively. After applying neutron rays to the sample filters

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Nobuhiko Murayama, Akira Harada,* Tomoaki Yoshikawa, Shoichi Arakawa ** Junji Sato,† Fujio Kimura, Tokiyoshi Toya, Takahisa Kobayashi, Takashi Koide, Naoshi Yano,†† Yako Suzuki, Isao Sato and Susumu Kurita: Applied Meteorology Reserch Division, MRI

* Magnetic Observatory ** Marine Division, JMA

† Office of planning, MRI †† Saitama University

in an atomic reactor, electron energy was measured to obtain the concentrations of the two atomic elements.

In order to find the actual local circulations and the related transport of air pollutants in the area concerned, trajectory experiments were conducted by tracking a non-lift balloon ("tetroon"). A tetroon equipped with a set of RAWIN was launched six times during the periods, and was tracked by the double-rawin technique which was to measure the height and position of tetroon. Though the 1980 field experiment was not necessarily conducted under the best conditions to observe the local circulation, we were able to have a valuable experience related to the experiments themselves. An evidence of local circulation under the prevailing synoptic flow which was found in both the field experiment and numerical experiment encourages us to further studies.

Following the preliminary experiment of the year 1980, the 1981 experiment on local circulation and the medium-range air pollutant transport was carried out in the Hiuchinada area, the central part of the Inland Sea and its coastal region. The pilot balloon and surface air observations were conducted hourly at eleven sites. The upper air temperature and humidity were measured 3-and 6-hourly respectively by slowly rising radiosondes at three sites. The air temperature, humidity and wind up to about 400 m in altitude were measured 3-hourly using tethered balloons. The sea water temperature was recored on ship about 10 Km off the Niihama coast. The upper air observations showed that the temperature over the Inland Sea varied in the same manner with that over the land, in spite of the difference of cooling or heating between land and sea surface. The temperature inversion layer often appeared several hundred meters above the sea surface. The inversion layer reached the maximum height of about 500 m in the morning and near the sea surface in the evening. A Doppler sodar was operated and wind and turbulence data were obtained during 10th-28th August in Niihama. Aircraft measurements were made of the vertical profiles and horizontal distribution of air temperatures, humidities, dew point temperatures, aerosols, O_3 and NO_X concentrations and surface temperatures in Hiuchinada and its surroundings through 8 flights. A non-lift balloon (tetroon) was released at 500 m in altitude and tracked by the double-rawin technique for several hours, 10 times in the Niihama area. The tetroons were flown to the west and no local circulation effect was distinct.

Three different chemical compounds, Europium, Holomium and Dysprosium, were released from the ground, boat and aircraft respectively, on 19th and 21st. The tracers were collected at 9 spots in Niihama and 11 spots in the surrounding area including 2 boats. After applying neutron rays to the sample filters in an atomic reactor, gamma ray energy was measured to get the concentrations of the three atomic elements. Whether the wind was inshore or off-shore, the high concentration was kept long and the air mass of the tracer appeared to stagnate in certain restricted areas near Niihama. The analysis of the surface and upper winds and surface concentrations showed that the high-concentration air mass hovered between land and sea owing to the land and sea breezes and could not move far away and that the pollutants were slow to diffuse.

The numerical simulation technique developed in the year 1980 was improved. The ground temperature was provided in definite form in the previous model, but it was determined by the energy balance based on the solar radiation and surface characteristics in the revised model. One of the characteristics of the wind data in the lower atmosphere over the Hiuchinada and its surroundings was the strengthening of the wind along the prevailing wind direction in the northern part of the Inland Sea, whenever the wind was easterly or westerly. The lower level jet was more remarkable at night than in the daytime. This was also successfully simulated in the numerical model.

The observation points of the year 1982 were distributed along the line passing through Kurashiki and Sakaide. The observations started soon after the end of the rainy season and terminated just before the coming of typhoons. The field experiment consisted of PIBAL, radio sounding, aircraft and other observations. A harmonic analysis of the upper wind variation was tried. The one-day component of the surface wind variation showed alternation of the sea breeze in the daytime and the land breeze in the nighttime. The hodograph of surface wind variations showed an ellipse with its longer axis perpendicular to the contour of the land surface. The wind direction backed below the 800 m-level and veered above the level which is in accord with the inertial wind direction change.

The vertical distribution of the wind was monitored continuously by the Doppler sodar system in Okayama. The results observed were compared with that of the nearby pibal and that of sodar in Niihama in the preceding year. It was found that the lower and upper winds shift simultaneously in Okayama. The updraft continued during weak easterly winds in the daytime and the downdraft prevailed during southeasterly winds. The variations of wind speed and direction were large when wind shifts and the variation of the vertical wind component was large at a specified time of the day, in a specified wind and so on.

It was found by aircraft measurements that polluted air was transported upwards vigorously by the local winds, especially by the valley wind in the daytime, and reached to the 3000 m level in the evening. The high concentration of pollutants appeared at two levels above the coast of the Inland Sea in the evening. The developed cumulus clouds seemed to help the vertical transport of ozone and scavenging of the aersols.

The tracer experiments were made at Tsukuba where the installation and equipment were enough to challenge the problems encountered in the previous experiments. It was found that the loss of tracer material in the form of minute particles due to the deposition to the ground surface was within 1% of the released material and the effect of the deposition on the plume was small.

Numerical simulation of the air pollution over the Inland Sea was carried out by the two step model. The first step was a three-dimensional time-dependent local wind model, which calculated wind velocity and the vertical diffusion coefficient. This model had been developed by the year 1981. The second step was the photochemical air pollution model which was also a three-dimensional model using the result of the first step model as input data. A second step model was further constructed with two submodels, a diffusion and advection model and a photochemical reaction model. The emission rate of pollutants was assumed to be a constant on the land surface whose altitude was less than 1000 meters. But on the southern side of Shikoku, no pollutant source was assumed. The results showed than ozone was transported upward by the well developed valley wind in the daytime, and the vertical distribution of pollutants agreed well with the aircraft observation. In the night time, however, there was some disagreement about the vertical transport of pollutants between simulation and observation.

In Chap. 1, ground-based observation is summarized with the description on the observation network and period, specifications of the low-level radiosonde and tethered balloon used, and examples of data with the format of MT data files stored.

In Chap. 2, the meteorological aspects of the atmospheric boundary layer in the Inland Sea area are discussed from the viewpoint of land-and-sea breeze by using the field observations. Individual paragraphs deal with wind field, mixing layer, vertical diffusivity and the local phenomena, i. e., convergence and divergence associated with land-and-sea breeze, and cyclonic vortex appearing at the time of wind direction inversion. Analyses of temperature and wind fields observed on the ship, at an inland and coastal stations are particularly shown by crosssectional presentations to clarify the features of the boundary layer.

In Chap. 3, air flow observation in the land-and-sea breeze regime is described with paragraphs on non-lift balloon observation and analysis of 1980 RUN 1. The data are presented with horizonatl trajectories and vertical fuluctuation both in Figure and Table.

In Chap. 4. aircraft measurements of various meteorological elements and air pollutants, such as NO_X, ozone and airborne particulates, are described in detail. We were rather successful in getting data on the areal distribution using a twin-engine plane. Instrumentation with specifications and calibration of each instrument used and the data acquisition system are first given, followed by the data observed and analyzed for 1980. 81 and 82 respectively. In particular, the vertical profiles of pollutants and the diurnal variation of surface temperature are analyzed, and the data of moisture fluctuation are discussed for 1981, while the diurnal variation of the pollutant distribution is discussed with vertical cross-sectional presentation. The abrupt change of pollutant concentration observed in a convective cloud is shown with a continuous record for 1982. Furthermore wind observations by use of Doppler navigation are discussed with the data obtained in trial experiment. The data acquisition system is shown in a flow chart which contains the MT file name.

In Chap. 5, Doppler sodar observation is presented, by which vertical profiles of wind field and turbulent parameter are obtained up to several hundred meters in altitude. After summarizing measurement concept, an example of the results observed is presented and the variation of the wind field in the boundary layer is discussed for the days of 1981 and 1982. In the last part, the MT file data-set of the Doppler sodar is dealt with.

In Chap. 6, transport or diffusion experiment conducted concurrently with field observation in 1980 and 1981 and that in Tsukuba in 1982 by use of activable multiple air tracers (AMAT) are overviewed. Here are presented a review of the foregoing studies, techniques of the AMAT, the sampling, a comparison with that using SF_6 tracer, the results of field experiments, the experiment to evaluate deposition of the tracer and the overall summary and conclusion.

In Chap. 7, Which is the last, under the title of numerical simulation of photo-chemical air pollution using the local wind model, the numerical experiment on transport of primary and secondary air pollutants is described in detail. Starting with the first paragraph on the role of local wind field upon air pollution, summary of a numerical model and mesoscale or local-scale meteorology model is presented with basic equation, heat budget at the ground, description of boundary layer, upper boundary condition and horizontal boundary and a simple one-way nesting method.

Secondly, an air pollution model is presented with the description of an advection-diffusion submodel and a parameterized photo-chemical reaction submodel. In the fourth paragraph, two-dimensional land-and-sea breeze and photo-chemical air pollution are discussed with computational condition, cross-sections of wind and pollutants, diurnal variation of pollutant concentration at the ground. Next, the local wind simulation at the calm in the Inland Sea area is discussed through comparison with field observation.

A part of this research was suppoted by the fund for researches on environmental pollution prevention granted to national research institutes.